Property of
Lake and River Enhancement Section
Division of Fish and Wildlife/IDNR
402 W. Washington Street, W-273
Indianapolis, IN 46204

WATERSHED DIAGNOSTIC STUDY
FOR
BRUSH CREEK RESERVOIR

Prepared for:

IDNR- Division of Water, Project Development Section
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Revised August 5, 2002

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EXECUTIVE SUMMARY

Brush Creek Reservoir is located in Jennings County approximately seven miles east-northeast of the City of North Vernon. The dam, spillway, and lower portion of the reservoir is found on property owned by the Muscatatuck Development Center (Muscatatuck) while the remainder of the reservoir and the immediate watershed is located on 1,841 acres owned by the IDNR-Division of Fish & Wildlife. The construction of the dam was started in 1952 and the structure was dedicated in July 1956.

The design surface area of the reservoir is 149 acres while the watershed reportedly encompasses 14.4 square miles that is long and narrow. The NRCS reports that 42% (2880 acres) of the watershed is farmland. 37% (2538 acres) is in pasture/hayland, 20% (1372 acres) is wooded and 1% (86 acres) is urban recreational area. Sedimentation has been documented as a concern in previous studies and, reportedly has reduced the storage capacity of the reservoir by approximately 20% since construction in the 1950s.

This project is intended to describe conditions and trends in Brush Creek Reservoir and its watershed and to identify potential water quality problems in subwatersheds. This assessment is to provide guidance for future land treatment project selection and to predict the impacts of those projects to Brush Creek. A diagnostic study takes a good look at conditions in the stream and in the watershed to try to understand or diagnose circumstances that, collectively, may be contributing to the water quality degradation suspected of occurring. The purpose of this diagnostic study then is to:

- Describe conditions and trends in Brush Creek Reservoir and the subwatersheds,
- Identify potential nonpoint source water quality problems,
- Propose specific direction for future work,
- Predict and assess success factors for future work.

The recommendations for enhancing the water quality of Brush Creek center on:

- Reducing the generation of nonpoint sources of pollutants, particularly nutrients and sediment from the watershed.
- Reducing the delivery of nonpoint sources of pollutants to Brush Creek, the Brush Creek Reservoir, and the Vernon Fork Muscatatuck River.

The Brush Creek Reservoir assessment resulted in data that indicate the reservoir has become eutrophic. Based on the IDEM Eutrophication Index, the reservoir scored 53 on a scale of 0 to 75 indicating eutrophication. Applying the Carlson Trophic State Index formulas netted similar results. Based on water transparency, the reservoir scored 66.2 and 67.3 based on Total Phosphorus. Chlorophyll-*a* measured in the reservoir resulted in a TSI of 44.2, which is in the mesotrophic range of that index however, chlorphyll-*a* sample filtering results may be skewed due to the use of the incorrect filters. That score then has discarded. The Carlson scale ranges from 20 to 80 with scores in the high 60s being eutrophic to hypereutrophic.

Total phosphorus loading was plotted with Vollenweider curves that predict allowable and excessive loading based on the mean depth. Total P loading was calculated to be 1.14 lb/ac/yr (0.128 $g/m^2/yr$), which is in the excessive range of the chart based on the mean depth of the reservoir.

Samples collected from Brush Creek proper and tributaries confirm watershed conditions that accelerate the eutrophication process. Storm water samples collected from ***all*** stream sampling locations had total P levels that were at least double the targeted level. Dissolved phosphorus levels were also elevated.

Samples collected from the hypolimnion of the reservoir however, suggested that the reservoir suffers from internal P loading as well. Therefore, the goal of management for this reservoir is not necessarily to eliminate productivity, but to prevent an unacceptable acceleration in the aging process to the point that desired values and uses of the reservoir are impaired.

This study has concluded that Brush Creek's lowered water quality may be a result of agricultural practices and overall lack of watershed management. Certain watershed conditions and prevailing practices warrant attention and further study by those wanting to preserve the habitat quality of Brush Creek and retard the eutrophication of Brush Creek Reservoir. Internal P loading will continue to be a contributing factor that is beyond the control of future watershed practices however watershed BMPs will determine future preservation or degradation of the reservoir.

The loss of 95% of the natural wetlands combined with intensive agricultural production are circumstances that support the presence of elevated nutrients and sediment in the runoff from the watershed- especially in the upper regions found in Ripley County. Even though some conservation tillage methods have likely helped to alleviate this condition, the silt and topsoil washed into the stream and reservoir during heavy rainfall events is still coating rocks and filling the pools and having a negative impact on the reservoir. Soil conservation efforts including conservation tillage and addition of filter strips should be intensified to prevent soil transport to the stream and reservoir and are regarded as the top two priorities. These grass buffers would also filter nutrients before they reach the waterways.

Third, access of cattle to the stream's ecosystem should be discouraged. The monitoring results at sample location #9 are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek. Also, the E. coli counts increased as the percentage of pasture increased within the subwatersheds.

Wildlife habitat in the form of forbs, shrubs and trees benefit wildlife and are also attractive- often adding to the value of real estate. Well managed wildlife habitats can save energy, protect soil and improve water and air quality. Trees and other plants hold soils in place during rain and wind. Vegetation helps keep sediment and contaminants from entering water bodies. In the right places, wildlife habitat can offer privacy and reduce dust and noise from road traffic. Plants also improve air quality by removing carbon dioxide from the air and replenishing it with oxygen.

Finally, wetland preservation, wetland restoration, and wetland construction should be pursued throughout the watershed- in that order. The development of additional wetlands to capture and treat agricultural fertilizer runoff deserves consideration in future studies.

1. Conservation Tillage

Crop-residue management through conservation tillage is one of the best and most cost-effective ways to reduce soil erosion. Conservation tillage and residue management can reduce machinery expenses and save soil, labor, fuel and money. Crop residues uniformly distributed over the soil surface will significantly reduce soil losses over an entire field. Conservation tillage is defined to be any tillage/planting system which leaves at least 30 percent of the field surface covered with crop residue after planting has been completed.

Conservation tillage systems offer numerous benefits that intensive or conventional tillage simply can't match:

- Reduces labor, saves time.
- Saves fuel.
- Reduces machinery wear.
- Improves soil tilth.
- Increases organic matter.
- Traps soil moisture to improve water availability.
- Reduces soil erosion.
- Improves water quality .
- Increases wildlife.
- Improves air quality.

2. Filter Strips

As an edge-of-the-field best management practice, filter strips are regarded as a reactive measure to soil erosion as compared to a proactive measure. Filter strips are a tool for effecting soil deposition and could be categorized a "second best" management practice to measures that prevent soil detachment in the first place. Nevertheless, filter strips are recommended as a top priority to prevent further degradation of water quality and sedimentation to the Brush Creek Reservoir.

Filter strips can be a very useful BMP to help reduce the amount of sediment and nutrients leaving the field. Filter-strip effectiveness is dependent on soil characteristics, land size, slope and shape, quality of vegetative cover within the filter, and local land use and climatic factors. In addition, periodic filter-strip maintenance is required to maintain its effectiveness in improving and protecting water quality. A filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that make an impact within the field. It should be recognized that best management practices can complement each other and, in many situations, BMPs need to be combined to optimize their benefits.

3. Livestock Exclusion

Samples collected from location #9 had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, slightly elevated temperature and conductivity readings, and elevated levels of Ammonia N, TKN, Organic N, Total N, Total P, and turbidity. Also, the E. coli counts increased as the percentage of pasture increased within the subwatersheds. There is an apparent trend as the E.coli count was lowest at point 10, where percent pasture was the lowest. At sample points 4, 5, and 6, where pasture constitutes 14-15% of the landuse, E. coli counts were the highest observed. These counts do not necessarily indicate cattle are directly accessing the streams however there does appear to be a correlation between the pasture landuse percentage and the coliform counts.

These results are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek. Access of cattle to the stream's ecosystem should be discouraged. Based on the observations of the apparent management regimes of cattle operations along the stream ecosystems, those subwatersheds with the highest concentrations of cattle operations should be focused on.

4. Wildlife Habitat

A century ago, numerous farm fields were small by today's standards. Brushy fencerows, idle crop fields, and unimproved pastures were common and farming provided an abundance of well-distributed wildlife cover. In the past half century, corn and soybean acreage increased while small grains and hay have decreased. In addition, woodlands are lost to agriculture, industrial, and residential development. Wildlife habitat improvement can greatly increase the abundance and variety of wild populations.

Many species of wildlife depend on "edge" conditions that can be provided by:

- Fencerow & Field Edge Plantings
- Tree Plantations
- Woods Edge Management
- "Odd Areas"

5. Wetlands

Based on an analysis of the hydric soils mapped in the soil surveys of Jennings and Ripley counties and located in the Brush Creek watershed, there were approximately 2,795 acres of wetlands in the Brush Creek watershed 200 years ago. This assessment suggests that wetland loss within the Brush Creek watershed is somewhat greater than the loss experienced Statewide during the same time period. The majority of this loss is attributed to artificial drainage and conversion to cropland.

The SWCDs are encouraged to apply for funds for the creation of additional treatment wetlands in areas, which currently do not benefit from an interface wetland. At the same time, the SWCDs may consider the restoration of particular wetlands within the watershed. Efforts should be directed toward ensuring that existing Federal laws protecting wetland areas are enforced within the Brush Creek watershed.

The recommendations, for the most part, involve private land where lack of incentive and financial ability on the landowner's part may limit implementation. Cost-sharing assistance may be available through the Lake and River Enhancement Program and other State or Federal programs. Typically, programs offer technical and financial assistance for design and construction projects and watershed land treatment projects.

I. INTRODUCTION

Brush Creek Reservoir is located in Jennings County approximately seven miles east-northeast of the City of North Vernon. The dam, spillway, and lower portion of the reservoir is found on property owned by the Muscatatuck Development Center (Muscatatuck) while the remainder of the reservoir and the immediate watershed is located on 1,841 acres owned by the IDNR-Division of Fish & Wildlife. The construction of the dam was started in 1952 and the structure was dedicated in July 1956.

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- Predict and assess success factors for future work.

While a diagnostic study is a significant milestone, it can't stop there. The SWCDs will need to commit themselves to going forward with design and implementation of watershed land treatments that may be recommended for the watershed.

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II. STREAM & WATERSHED SETTING

1) Location

Brush Creek is a tributary of the Vernon Fork of the Muscatatuck River. The main channel is nine miles in length originating in northwestern Ripley County and flowing through Jennings County until its confluence with the Vernon Fork of the Muscatatuck River north of the Muscatatuck State Development Center facility. Figure II-1 is a topographic map with the approximate watershed boundary depicted.

2) Morphometry

Brush Creek has a stream length above the reservoir of approximately 8.5 miles. The straight-line distance between the head of the stream and the reservoir inlet is approximately 7.4 miles. The elevation at the head of the stream is in the vicinity of 910 Mean Sea Level (MSL) while the design pool of the reservoir is approximately 715 MSL. Therefore, the channel slope is calculated to be around 0.43% (23 feet per mile) while the overall valley profile is approximately 0.5% or 26 feet per mile.

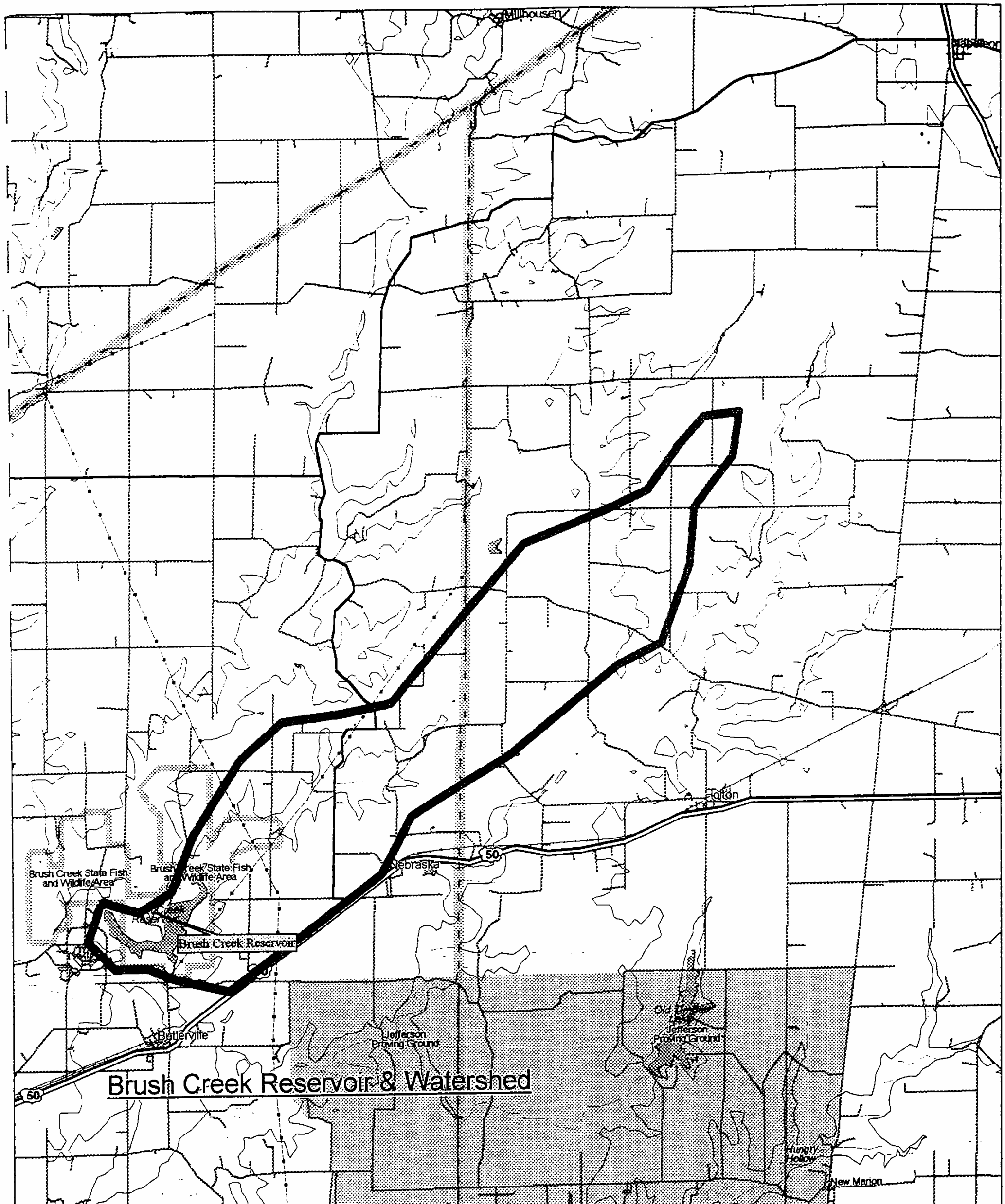
3) Watershed size and characteristics

The Brush Creek watershed is approximately 14.4 square miles (9,240 acres) in size. The basin is unusually narrow in that it rarely is over one and a half miles wide while the length extends some ten miles. Upland areas are indistinctly dissected with diverse topographic features. Drainage patterns are moderately well defined, as subwatershed divides are typically flat and broad with valley walls that are steep. The bottomlands of the valleys are narrow flood plains and most of the level soils in the watershed are found on the ridgetops.

The watershed lies in Jennings and Ripley Counties. Table II-1 shows the relative and actual size of each county representation.

Table II-1
Brush Creek Watershed
Relative & Actual Size by County

County	Acreage	Square Miles	% of Total
Jennings	4,990	7.8	54
Ripley	4,250	6.6	46
Total	9,240	14.4	100



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 4000 ft Scale: 1 : 100,000 Detail: 10-7 Datum: WGS84

FIGURE II-1

Due to the long narrow configuration of the watershed, most sub-watersheds are not of significant size. One exception is the sub-watershed of an unnamed tributary to Brush Creek that converges approximately one mile upstream (east) of the Ripley County line. This subwatershed is approximately 1,400 acres that represents 30% of the watershed acreage found in Ripley County. The watershed as a whole drains generally to the southwest.

In the absence of multiple significant subwatersheds, attention within this study will focus on dominant landuse patterns that closely approximate county lines. There is a pronounced difference in the intensity of agricultural production in Ripley County versus Jennings County when examining the Brush Creek watershed. Conversely, the portion of the watershed in Jennings County that is forested or woodland, is much greater that the proportion in Ripley County.

The Brush Creek watershed is not heavily impacted by residential or commercial development. The Muscatatuck grounds and the town of Nebraska are at the fringe of the watershed divide and only fractions of these areas drain to Brush Creek.

4) Geology

The reservoir is located in the physiographic region referred to as the Muscatatuck Regional Slope. It is interpreted to be a structural plain or stripped surface on the resistant westward dipping underlying Devonian and Silurian carbonate rocks. The valleys are generally steep sided and moderately deep with the stream having down cut through a thin cover of unconsolidated glacial deposits into the underlying limestone.

The upland areas are covered with glacial till, Illinoian or older in age. This till is generally less than 25 feet thick in this area. Beneath the Brush Creek floodplain is alluvium that consists of silts, clays, and sands with a maximum thickness of about 10 to 15 feet. Along the sides of the stream, terrace deposits may be found at certain locations. The valley sides are covered with a colluvium layer that is highly variable in thickness and consists of both fragments of the bedrock and glacial material from the upland areas.

The bedrock in this area consists of Silurian and Devonian rocks which are predominantly carbonates. It consists of less than 5 feet of highly weathered, brown, medium-grained sandstone that is stratigraphically absent in many places in southern Indiana. Beneath that is the Geneva Dolomite that consists of a gray, fine-grained dolomite containing a few thin chert layers. Only a minor amount of solution features have been observed in this unit in this part of Indiana. The solutioning has mainly been in the slight local widening of bedding planes and joints.

5) Soils

The topography of the Brush Creek watershed is characterized by broad nearly level areas and gently sloping soils of uplands. These soils are on the Illinoian till plain, which is older that the Wisconsin till plain.

Brush Creek has dissected and entrenched into the Illinoian till and has exposed the underlying limestone or shale bedrock in places. Bottomland in the floodplain of the Creek is generally narrow.

Drainage patterns are generally well developed with broad flat, undulating plains, and steeper areas along streams and drainageways. Drainage is generally to the southwest.

A. Soil Associations

A General Soil Map of soil associations is presented as Figure II-2. A general description, by county, is included with the map. These various soil associations are further discussed by county in the succeeding paragraphs.

1. Jennings County

Three soil associations are represented in the portion of the watershed found in Martin County. The Genesee-Eel map unit consists mainly of nearly level soils on flood plains along Brush Creek and larger streams. These soils are deep, well drained and moderately well drained and were formed in recent loamy alluvium.

Soils in this association are used for corn and soybeans, even though susceptible to stream flooding during the growing season which can destroy the crop. Flooding is the major hazard in use and management of these soils.

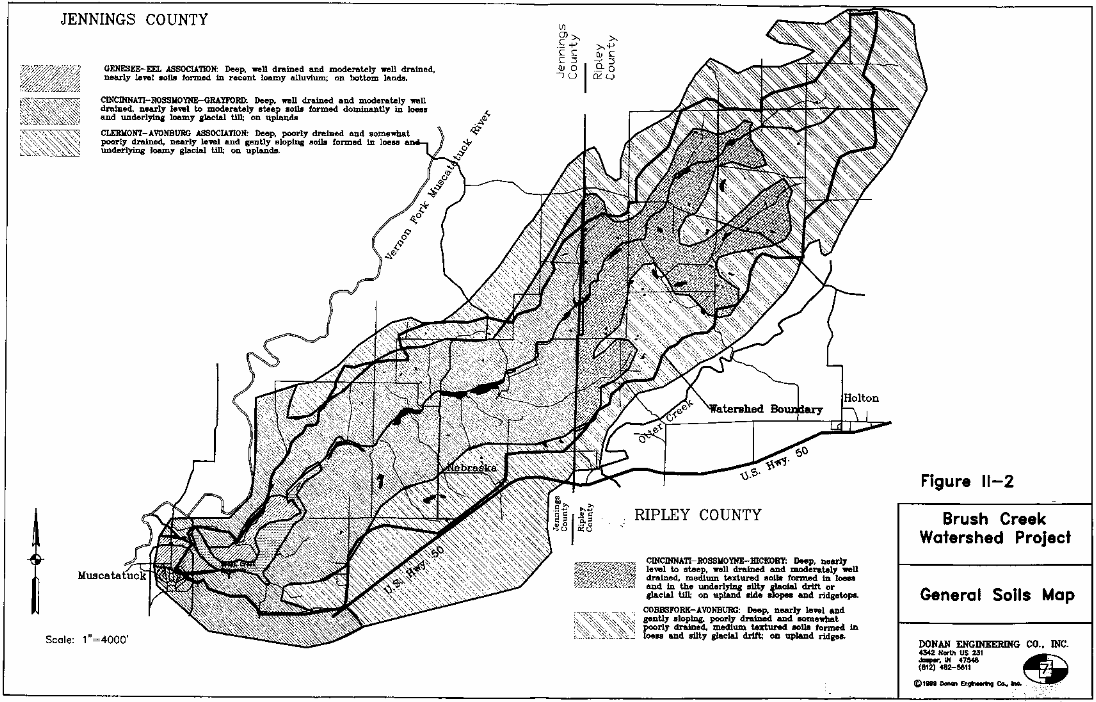
The Cincinnati-Rossmoyne-Grayford association consists mainly of nearly level to moderately steep soils on ridgetops, breaks, and hillsides. The soils are deep, well drained to moderately well drained and were formed dominantly in loess and underlying loamy glacial till.

Most areas of the soils in this association are used for small grain, hay, and pasture or are wooded but some is used for corn and soybeans. Although natural fertility is low, these soils respond well to lime and fertilizer. They are improved by additions of plant residue. Erosion and runoff are the main hazards in use and management of these soils.

Clermont-Avonburg association soils are deep, poorly drained and somewhat poorly drained, nearly level and gently sloping soils formed in loess and underlying loamy glacial till. This soil association consists mainly of nearly level and gently sloping soils on broad ridges.

The soils in this association are used mainly for cultivated crops- especially corn and soybeans. These soils are among the most productive on uplands in the area, responding well to lime and fertilizer. Plant residues and deep-rooted legumes help to improve these soils.

Excessive wetness is the main limitation in use and management of these soils. Artificial drainage can reduce this limitation.



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2. Ripley County

There are two soil associations identified in the Brush Creek watershed area, which occur in Ripley County. The Cincinnati-Rossmoyne-Hickory soils are deep, nearly level to steep, well drained and moderately well drained. These soils are medium textured having been formed in loess and in the underlying silty glacial drift or glacial till. The map unit is on ridges and side slopes along drainageways on the loess-covered Illinoian till plain. Areas are large and are scattered throughout the watershed and county.

This map unit is used mainly for crops and for hay and pasture. The more steeply sloping areas are used for woodland. Erosion and slope are the main limitations.

Cobbsfork-Avonburg soils are deep, nearly level and gently sloping, poorly drained and somewhat poorly drained soils. These soils are medium textured soils formed in loess and silty glacial drift. Soils in this association are found on broad ridges between drainageways and these areas are generally large and found throughout the county.

This map unit also is used mainly for crops. Most of the acreage has been cleared, and some areas have been drained. Some wet, undrained areas are wooded. Wetness and erosion are the main limitations if the soils are used for crop production. Artificial drainage is nearly necessary for conventional crop production.

B. Hydric Soils

A hydric soil is a soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions. This lack of oxygen in the soil can lead to the formation of certain observable characteristics in wetland soils, such as a thick layer of organic matter (non-decomposed plant materials) in the upper part of the soil column. Other observable features include oxidized root channels and redoximorphic features (concentrations and depletions of Iron and other elements, i.e., mottling, gleying).

The Brush Creek watershed is generally in an upland setting while the majority of hydric soils occur lower in the landscape. Hydric soils are formed, however, in upland depressional or flat areas that have inherent poor drainage. Such is the case in the Brush Creek watershed. Based on an analysis of the hydric soils mapped in the soil surveys of the two counties, there are four areas where Wakeland silt loam is mapped, which is included on the list of hydric soils of Indiana. These four areas are at headwater areas to unnamed tributaries of Brush Creek and total approximately 42 acres or about 0.4% of the watershed. In upland areas however, there are Clermont silt loam (Jennings County) and Cobbsfork silt loam (Ripley County) that comprise nearly 30% of the watershed.

Table II-2
Hydric Soils Acreage in Brush Creek Watershed

County	Hydric Soil	Hydric Soil Acreage	% of Watershed	% of Total Hydric Soil Acres
Jennings	Clermont	722	7.8	25.8
	Wakeland	25	0.2	0.9
Ripley	Cobbsfork	2031	22.0	72.7
	Wakeland	17	0.2	0.6
Total		**2795**	**30.2**	**100**

Although mapped as hydric soils, these areas are not delineated on National Wetland Inventory maps as potential wetland. Refer to Figure II-3, which maps these areas and NWI delineations. The NWI delineations include excavated ponds as well as wetland areas along the stream corridors.

C. Highly Erodible Land

These lands have been defined in order to identify areas on which erosion control efforts should be concentrated. The definition is based on Erosion Indexes derived from certain variables of the Universal Soil Loss Equation and the Wind Erosion Equation. The indexes are the quotient of tons of soil loss by erosion predicted for bare ground divided by the sustainable soil loss (T factor).

To mitigate soil erosion on highly erodible land (HEL), the 1985 Farm Bill introduced the Conservation Compliance and Sodbuster programs. These programs require farmers to implement approved soil conservation systems on land defined by USDA as highly erodible lands to receive certain USDA program benefits. In 1992, the USDA's Natural Resource Conservation Service (NRCS) designated 105 million acres, roughly one-third of total U.S. cropland, as HEL.

Highly Erodible Land (HEL) is land that has a soil erodibility index (EI) of 8 or more. The EI provides a numerical expression of the potential for a soil to erode considering the physical and chemical properties of the soil and the climatic conditions where it is located. The higher the index, the greater the investment needed to maintain the productivity of the soil if intensively cropped.

The majority of the soils in the Brush Creek Watershed are classified as highly erodible lands or at least potentially highly erodible lands (PHEL). In the future, digitized soil survey maps will provide opportunity for mapping these sensitive soil types at the county and watershed level. Published soil surveys for the two counties involved in the Brush Creek watershed were reviewed and correlated with NRCS Field Office Technical Guide information to summarize the presence of highly erodible lands in the watershed. Table II-3 presents that information.

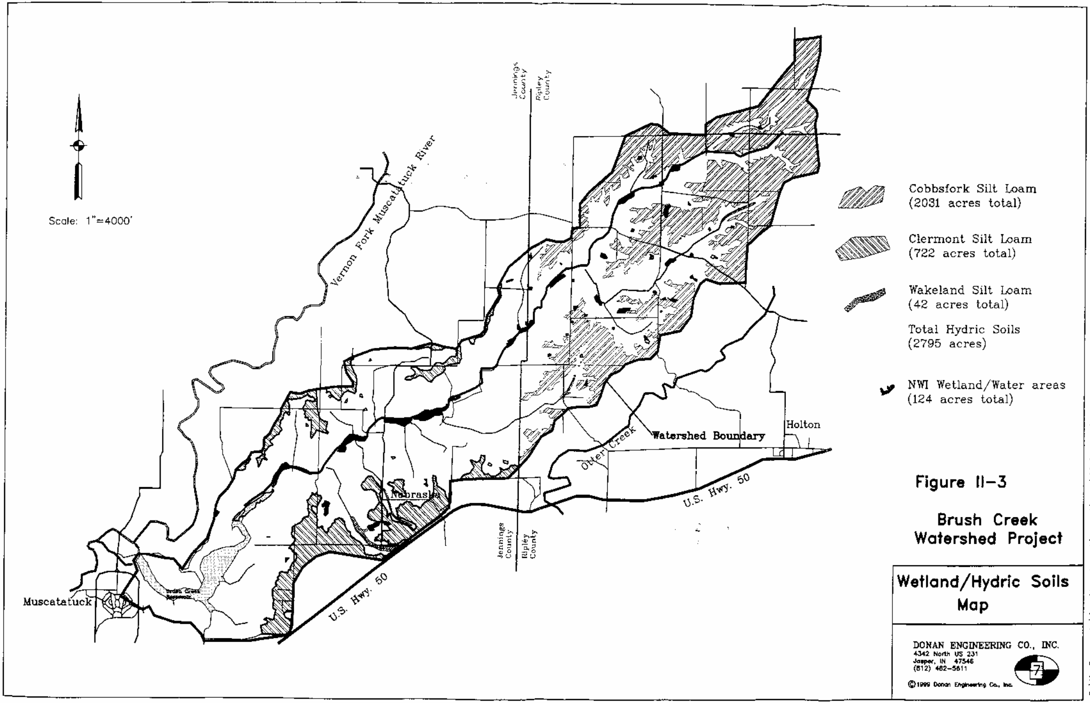

Figure II-3

Brush Creek Watershed Project

Wetland/Hydric Soils Map

Table II-3
County HEL Soils

Jennings County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
CnC2	Cincinnati	1	8300	3.4
CnC3	Cincinnati	1	6600	2.7
CnD2	Cincinnati	1	2900	1.2
CnD3	Cincinnati	1	2100	.9
CyF	Corydon	1	3700	1.5
ElC2	Elkinsville	1	560	.2
GfC2	Grayford	1	3000	1.2
GfC3	Grayford	1	1350	.6
GfD2	Grayford	1	2750	1.1
GfD3	Grayford	1	2200	.9
GoE	Grayford	1	2850	1.2
HkE2	Hickory	1	8900	3.7
HkF	Hickory	1	5500	2.3
JnC3	Jennings	1	2450	1.0
JnD2	Jennings	1	800	.3
JnD3	Jennings	1	600	.2
MmC2	Miami	1	770	.3
MmD2	Miami	1	330	.1
MoC3	Miami	1	800	.3
PaC2	Parke	1	1800	.8
PaC3	Parke	1	910	.4
PcC2	Pekin	1	780	.3
TrC2	Trappist	1	900	.4
TrD2	Trappist	1	600	.2
TsC3	Trappist	1	1550	.6
TsD3	Trappist	1	1100	.5
WkE2	Weikert	1	1250	.5
AvB2	Avonburg	2	3250	1.4
CnB2	Cincinnati	2	890	.4
CoC2	Cincinnati	2	20750	8.6
ElB2	Elkinsville	2	402	.2
FrB2	Fincastle	2	3000	1.2
GfB2	Grayford	2	1500	.6
JnB2	Jennings	2	1900	.8
JnC2	Jennings	2	3400	1.4
PaB2	Parke	2	2550	1.1
PcB2	Pekin	2	1950	.8
RsB2	Rossmoyne	2	21000	8.8
RsB3	Rossmoyne	2	1200	.5
	Subtotal	1	65350	27.1
	Subtotal	2	61792	25.6
	Total		**127142**	**52.7**

Table II-3 (Con't)
County HEL Soils

Ripley County

Map symbol	Soil Name	HEL Class	Acres	Percent of County
BeC2	Bonnell	1	463	.2
BeD3	Bonnell	1	925	.3
BeE	Bonnell	1	1031	.4
CbD2	Carmel	1	2867	1.0
CbE	Carmel	1	1413	.5
CcC2	Cincinnati	1	20657	7.2
CcC3	Cincinnati	1	12328	4.3
CcD2	Cincinnati	1	1467	.5
EdE	Eden	1	1793	.6
EdF	Eden	1	9367	3.3
ErF	Rock Outcrop	1	2146	.7
GrD2	Grayford	1	3043	1.1
GrE	Grayford	1	3376	1.2
HkD2	Hickory	1	8138	2.8
HkD3	Hickory	1	3507	1.2
HkE	Hickory	1	16783	5.8
SwC2	Switzereland	1	3103	1
SwD2	Switzereland	1	693	.2
AvB2	Avonburg	2	13231	4.6
CcB2	Cincinnati	2	11840	4.1
EkB	Elkinsville	2	1090	.4
EkC2	Elkinsville	2	399	.1
PeB2	Pekin	2	1590	.5
PT	Pits	2	182	.1
RoB2	Rossmoyne	2	36156	12.6
RyC2	Ryker	2	1455	.5
	Subtotal	1	93100	32.4
	Subtotal	2	65943	23.0
	Total		159043	55.4

In the tables, the HEL classification of 1 refers to highly erodible soil while a value of 2 in this column identifies a soil map unit that is potentially highly erodible. Table II-4 summarizes the totals and proportions from the two counties involved. Without digitized soil maps, it is beyond the scope of this study to map or accurately quantify the HEL acreage for the watershed. A correlation can be derived however based on the percentage HEL acreage in each county and the acreage of the county that occurs in the watershed

Table II-4
HEL Acreage in Brush Creek Watershed

County	Jennings	Ripley	Total
Acres in watershed	4990	4250	9240
% of County that is HEL	52.7	55.4	
HEL acreage in watershed (Assumes equal distribution of HEL acreage throughout county)	2630	2354	4984
			54%

6) Climate

In the Brush Creek watershed, winters are cold and it is generally quite hot in the summer. Winter precipitation, some of which is in the form of snowstorms, results in a good accumulation of soil moisture by spring. The accumulated soil moisture minimizes drought during the summer on most soils. The normal annual precipitation is adequate for all of the crops that are suited to the temperature and length of the growing season.

In the winter, the average daily temperature is about 31 degrees F and the average daily minimum is 21 degrees. In summer the average temperature is 72 degrees F and the average daily maximum is 84 degrees. The total annual precipitation is about 40 inches, which includes an average annual snowfall of about 17 inches.

7) Sensitive Areas & Critical Habitats

Information on critical habitats, unique natural areas, and protected species was requested from the IDNR Division of Nature Preserves. The Division responded stating that the Indiana Natural Heritage Data Center has been checked and there are no endangered, threatened, or rare species documented from the Brush Creek watershed area. Their response also stated there were no listings of high quality natural communities or natural areas documented. A copy of the Division's correspondence is included in the Appendix.

8) Historic & Culturally Significant Areas

Donan requested information on historic sites and structures and other archaeologically pertinent information for the project area from the Indiana Division of Historic Preservation and Archaeology. Based on a review of the Indiana Register of Historic Sites and Structures and the National Register of Historic Places, the Division reports that there are no known archaeological sites listed.

Established under the National Historic Preservation Act of 1966, the National Register has identified and documented over 73,000 sites that are significant in American history and culture. The National Register Information Service database was accessed on the Internet and found sites within Ripley and Jennings County, however all listings were outside the Brush Creek watershed.

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III. HISTORICAL DATA

1) Overview

The data available for characterizing the water quality of Brush Creek in the past is found to be limited and diverse. There have been attempts to monitor water quality by various groups and, in some instances, the monitoring has been repeated for significant durations and frequencies. For the most part however, these efforts of the various groups have been dispersed well along the stream to the extent that they are generally unrelated. The historical data includes Indiana Department of Environmental Management (IDEM) data, volunteer monitoring by an Eastern Greene High School group, and fisheries surveys by the Indiana Department of Natural Resources- Division of Fish & Wildlife and others.

2) Fisheries Reports

The fish population in the Brush Creek watershed above the dam was not eradicated before or after dam construction. Thus, the fish already present in the creek stocked the reservoir as it filled. However, some largemouth bass fingerlings, channel catfish, and probably redear sunfish were stocked by local conservation and sportsman's clubs several times during the fifties.

The land around the reservoir was owned by the State Hospital until January 1969. At that time the hospital deeded some of its land (1,136 acres) to the Department of Natural Resources.

The fishery of Brush Creek Reservoir is monitored by the Indiana Department of Natural Resources- Division of Fish & Wildlife. Lake surveys have been performed and fish management reports have been prepared for the reservoir since 1962. Reports were prepared for 1962, 1970, 1973, 1976, 1982, 1991, and 1999. District fisheries biologists have identified Brush Creek Reservoir as a significant bass-panfish fishery, although this fishery is reportedly diminishing and in the 1999 survey, gizzard shad were found which are having a marked negative impact on the fishery in the past few years. A summary of the individual reports follow.

A. Semi-Annual Report for Lake Investigations, Weaver, 1962

The first fishery survey was conducted in 1962. Biologists reported that the bluegill and redear fishery appeared to have reached its peak and was deteriorating. However, the crappie fishery was satisfactory and there was an unexploited channel and blue catfish fishery. Overall, the reservoir was providing an acceptable fishery.

Table III-1
Semi-Annual Report for Lake Investigations, Weaver, 1962
Physical and Chemical Characteristics

	May 15, 1962		August 22, 1962		November 14, 1962	
Depth (m)	°C	DO (mg/L)	°C	DO (mg/L)	°C	DO (mg/L)
Surface	28.8		27.8		9.4	
1	25.4	11.8	27.3	11.6	9.0	10.1
2	22.1		26.9		8.9	
3	19.8	12.6	26.7	11.6	8.9	
4	14.8		19.5	11.3	8.8	
5	11.3	9.1	15.5	4.8	8.8	
6	10.1	0.6	13.6	0.5	8.8	
7	9.9		11.7	0.0	8.7	

Fish Size, Age, and Rate of Growth

	Gill Nets		Traps	
Species	Number	Ave.Wt. (oz)	Number	Ave. Wt. (oz)
White crappie	34	2.4	136	2.0
Black crappie	26	3.4	96	2.4
Bluegill	16	1.6	104	1.6
Redear	6	4.3	30	2.5
Yellow bullhead	20	7.4	3	5.9
Channel catfish	16	14.2	0	
Green sunfish	2	1.3	9	1.3
Black bullhead	11	11.9	2	15
Brown bullhead	12	14.3	0	
White sucker	10	22.7	1	29.3
Spotted sucker	10	12.9	0	
Largemouth bass	9	9.4	0	
Long ear	0		8	0.8
Blue catfish	5	7.2	0	
TOTAL	177		389	

B. Fish Management Report- Zook, 1970

A fishery survey in 1970 found the reservoir fishery in good to excellent condition for bass, bluegill, and redear. Biologists also reported that 14% of the fish sampled were suckers, which were providing a fishery in Brush Creek above the reservoir during their spring migration.

Table III-2
Fish Management Report- Zook, 1970
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	76	10.2	68	9.0
2	76			
4	76			
5		10.2		
6	75.5			
8	75			
10	75	9.4		
12	74.5			
14	69			
15		6.1		
16	62			
18	58			
20	57	7.2		
22	55			
24	54			
25		3.1	96	7.5
26	53			
28- bottom	53			

Species and Relative Abundance

Common Name	Number	Percentage
Bluegill	238	38.6
Redear	121	19.6
Largemouth Bass	79	12.8
Golden Redhorse	70	11.3
Warmouth	35	5.7
Longear Sunfish	29	4.7
White Sucker	15	2.4
Black Crappie	12	1.9
Yellow Bullhead	9	1.5
Black Bullhead	6	1.0
White Crappie	3	.5
Brook Silverside		

C. Fish Management Report- Janisch, 1973

After a fishery survey in 1973, biologists reported that Brush Creek had an above average bluegill, redear, and black crappie fishery and an average largemouth bass fishery. The number of suckers in the sample had increased to 21.5%. It was recommended that northern pike be introduced and stocked regularly to utilize the sucker population. The D.N.R. made an introductory stocking in May 1975 of 11,097 two-inch pike fingerlings (66 pike/acre). It was also recommended that regular stockings of channel catfish be initiated. A total of 1,715 channels (average length 4.8 inches) were stocked in November 1976.

Table III-3
Fish Management Report- Janisch, 1973
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	84.0	10.6	85.5	10.0
2	82.0			
4	79.0			
5		11.2		
6	76.5			
8	70.0			
10	65.0	2.8		
12	63.0			
14	61.0			
15		0.4		
16	59.0			
18	57.0			
20	56.0	0.0		
22	55.0			
24	54.0			
25		0.0		
26	54.0			
28- bottom	54.0	0.0	153.9	7.0

Species and Relative Abundance

Common Name	Number	Percentage
Bluegill	280	39.66
White Sucker	148	20.96
Largemouth Bass	99	14.02
Longear Sunfish	75	10.62
Redear Sunfish	28	3.97
Black Crappie	27	3.82
Warmouth	26	3.68
Yellow Bullhead	9	1.28
Log Perch	4	.57
Hybrid Sunfish	3	.43
Golden Redhorse	2	.28
Spotted Sucker	2	.28
Black Bullhead	2	.28
Brown Bullhead	1	.14
Brook Silverside		

D. Fish Management Report- Lehman, 1976

A fishery survey was conducted August 24-26, 1976 to check condition factors (a measure of relative plumpness) and growth rates of selected gamefish in Brush Creek Reservoir. Survey effort consisted of A.C. electrofishing for 2.1 hours and fishing experimental gill nets for 288 hours. A total of 1,492 fish representing 13 species were collected. Bluegill comprised 53.4% of the sample followed by largemouth bass (13.9%), longear sunfish (9.6%), redear sunfish (7.2%), white sucker (6.3%), warmouth (4.1%), spotted sucker (1.6%), black crappie (1.5%), yellow bullhead (1.5%), hybrid sunfish, black bullhead, and logperch (0.8% combined). Brook silversides were also found in the lake but were not included in the sample total. No northern pike from the 1975 fingerling stocking were seen.

The most abundant fish by number were bluegill but they ranked third in abundance by weight. The sample was dominated by large 1976 and 1975 year classes (age O+ and I+ bluegill). Bluegill reproduction is excellent as evidenced by an abundance of 1.0 to 3.0 inch fish. Bluegill exhibited average condition factors and above average growth rates. One-year old bluegill ranged up to 5.5 inches. Of 796 bluegill collected, 28.4% were catchable size (6.0 inches and larger).

Table III-4
Fish Management Report- Lehman, 1976
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	83.0	12.0	119.7	10.0 +
2	82.0			
4	81.0			
5		12.0		
6	81.0			
8	77.0			
10	75.0	2.0		
12	73.0			
14	70.0			
15		0.0		
16	67.0			
18	64.0			
20	62.0	0.0		
22	60.0			
24	59.0			
25-bottom	58.0	0.0	188.1	10.0 +
26				
28				

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Bluegill	796	53.4	74.84	17.6
Largemouth Bass	208	13.9	81.01	19.0
Longear Sunfish	143	9.6	7.24	1.7
Redear Sunfish	107	7.2	20.06	4.7
White Sucker	94	6.3	167.06	39.3
Warmouth	61	4.1	6.42	1.5
Spotted Sucker	24	1.6	43.68	10.3
Black Crappie	23	1.5	8.37	2.0
Yellow Bullhead	23	1.5	12.09	2.8
Hybrid Sunfish	8	0.5	1.48	0.4
Black Bullhead	3	0.2	3.19	0.8
Logperch	2	0.1	0.05	*
Brook Silverside	Present			

E. Fish Management Report- Lehman, 1982

A fish kill of unknown causes was reported to State authorities during July of 1982. Several thousand fish (mostly panfish) were killed. However, the fish kill did not appear to have an adverse effect on panfish populations in the lake as substantial numbers of large bluegill, redear, and black crappie were collected in this survey. Weights and growth rates of panfish and largemouth bass were also found to be satisfactory for southeastern Indiana. For the past 25 years, Brush Creek Reservoir had been a very popular fishing spot for Indiana and Ohio fishermen. According to this survey, the lake was expected to continue to provide good panfishing opportunities.

Twenty-five carp (11 to 29.5 inches) were collected in this survey. Carp had not been collected in any previous survey but fishermen reported that they have been aware of carp in the lake for awhile. The effect of carp on the fishery was planned to be monitored in future fishery surveys.

Three attempts to establish a population of northern pike in the reservoir were made from 1975 to 1978:

1. As recommended, pike fingerlings were introduced in 1975. However, that stocking was apparently unsuccessful as none of those Pike were collected during the 1976 or 1982 fishery surveys. The fact that those pike did not survive has been attributed to their small size (2 inches) and low number (66 pike/acre) when stocked into the lake.

2. In December of 1976, 127 adults were stocked into the reservoir through the ice. It was hoped those adults would spawn on submerged shoreline vegetation. The pike apparently survived the stocking as fishermen reported catching some of them during April and May of 1977 in the lake and also in the river below the lake. However, none of the adults or their young were collected in this survey. Apparently, none of the small pike, which may have been hatched that spring, escaped predation by other fish.

3. Pike fingerlings were stocked again in the spring of 1978 but the stocking rate was increased to 86 pike/acre. However, none of those fish were collected in this survey either. It appeared that this stocking was also unsuccessful in spite of the higher stocking rate.

None of the pike stockings, which were made from 1975 to 1978, resulted in establishing a pike population. Similar results have also been noted where two-inch pike or adult pike have been stocked into other southern Indiana lakes with established fish populations. The small pike, which are stocked or produced by spawning adults, are too susceptible to predation.

Attempts to establish a northern pike population by stocking small fingerlings or adult spawners should be discontinued, according to this survey. It was recommended that only advanced fingerlings (9 inches or larger) be used in the future if northern pike or tiger muskie are to be stocked into Brush Creek Reservoir. No further northern pike or tiger muskie stockings were recommended.

This report stated that the lake was then providing excellent fishing opportunities with existing fish populations.

Table III-5
Fish Management Report- Lehman, 1982
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	75.2	14	85.5	9.8
2	75.2			
4	75.2			
5		13		
6	74.3			
8	73.4			
10	71.6	11	102.6	9.8
12	70.7			
14	68.0			
15	4			
16	62.6			
18	59.9			
20	57.2	0.0	153.9	7.3
22	56.3			
24	55.4			
25		0.0		
26	54.5			
28- bottom	53.6	0.0	171.0	6.8

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Bluegill	458	35.4	84.32	12.4
Largemouth Bass	285	22.0	99.19	14.6
Spotted Sucker	150	11.6	245.77	36.1
Black Crappie	113	8.7	16.75	2.5
Redear Sunfish	72	5.6	42.88	6.3
Longear Sunfish	61	4.7	3.37	0.5
White Sucker	57	4.4	89.49	13.2
Carp	25	1.9	60.49	8.9
Warmouth	24	1.9	2.95	0.4
Hybrid Sunfish	19	1.5	7.31	1.1
Black Bullhead	7	0.5	5.52	0.8
Common Shiner	5	0.4	0.76	0.1
Bluntnose Minnow	5	0.4	0.03	*
Channel Catfish	4	0.3	17.26	2.5
Yellow Bullhead	4	0.3	1.69	0.2
White Crappie	2	0.2	0.88	0.1
Golden Redhorse	1	0.1	1.46	0.2
Logperch	1	0.1	1.46	0.2
Brook Silverside	Present			

F. Fish Management Report- Lehman, 1991

According to this survey, bluegills provided excellent panfishing opportunities at that time. Redear sunfish, longear sunfish, warmouth, hybrid sunfish, and crappies also provided panfishing opportunities. Anglers reported catching bluegills up to 10 inches and redear up to 11 inches.

Largemouth bass growth rates were satisfactory enough although they appeared to have declined steadily since last measured in 1982. Sublegal bass were abundant and provided many catch-and-release fishing opportunities. Some legal bass were also present.

Due to predation on channel catfish eggs and young, catfish have never been expected to establish a self-sustaining population in Brush Creek Reservoir. Since 1976, nearly 22,250 channel catfish have been supplementally stocked by the IDNR to artificially provide channel catfishing opportunities. Survival and growth of catfish fingerlings appears to be satisfactory at this time.

The primary fish management goals at Brush Creek Reservoir were stated to be; 1) maintain quality fishing opportunities for panfish (chiefly bluegills) and channel catfish; and 2) maintain adequate bass growth to provide some fishing opportunities for bass exceeding the size limit. In order to meet those goals, the following recommendations were made:

1. Maintain the 14-inch minimum size limit to prevent overharvest of largemouth bass, the primary predator in the lake.
2. Regularly stock channel catfish at 25 catfish/acre every three years. Channel catfish should average at least 8-inches long when stocked to reduce predation by bass. The next regular stocking is scheduled for 1992. Catfish stockings should be publicized.

Table III-6
Fish Management Report- Lehman, 1991
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	89.0	13.0	103-120	10.0 +
2	88.0			
4	85.0			
5		13.0	86-103	10.0 +
6	83.0			
8	76.0			
10	68.0	10.0	103-120	10.0 +
12	63.0			
14	58.0			
15		1.0	120-137	9.3
16	56.0			
18	55.0			
20	5.0	0.0	120-137	8.7
22	54.0			
24	54.0			
25		0.0	137-154	7.8
26	54.0			
28	53.0			
29-bottom	52.0			

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Bluegill	183	37.7	22.28	14.9
Largemouth Bass	131	27.0	61.66	41.1
Longear Sunfish	77	15.8	5.33	3.6
Warmouth	18	3.7	2.82	1.9
Logperch	18	3.7	0.45	0.3.
Channel Catfish	16	3.3	7.38	4.9
Redear Sunfish	16	3.3	7.38	4.9
Hybrid Sunfish	12	2.5	3.77	2.5
Brook Silverside	4	0.8	0.01	**
Black Bullhead	3	0.6	5.60	3.7
White Crappie	3	0.6	0.23	0.2
Spotted Sucker	2	0.4	6.07	4.0
Common Carp	1	0.2	13.00	8.7
Yellow Bullhead	1	0.2	0.27	0.2
Common Shiner	1	0.2	0.01	**

G. Fish Management Report- Lehman, 1999

Gizzard shad had never been collected in this impoundment prior to this survey. Whether their introduction was accidental or intentional, it had a negative effect on the fishery. Shad, which offer no angling opportunities, had replaced 35% of the fish by number and 21 % by weight. Thus, it is a wonder that anglers had noticed a decline in fishing at Brush Creek Reservoir.

Small shad do provide food for other fishes. However, shad are a problem for desirable game fish when they become so abundant that they seriously compete with small game fish for food, which negatively affects their survival. Another problem is that predatory pressure is diverted away from panfish and common carp where it is needed in this reservoir to keep those species under control.

According to this survey, bluegills were providing marginal panfishing opportunities. Although electrofishing catch rates were up 117% compared to 1991, growth has declined. No bluegill were collected over 6.7 inches long.

Bass electrofishing catch rates were down 57% since 1991 but bass continued to provide some fishing opportunities for sublegal and legal fish. Crappie comprised 15% of the population by number compared to only 1 % in 1991. Due to the presence of gizzard shad, Brush Creek Reservoir appeared to be shifting from a bass/bluegill lake to a crappie, channel catfish, and common carp lake.

Options to eradicate the fish population at low pool in the fall or early winter were encouraged in the report. The report recommends maintaining the 14-inch largemouth bass size limit and channel catfish stocking every two years until a decision is made on a possible lake renovation.

Table III-7
Fish Management Report- Lehman, 1999
Physical and Chemical Characteristics

Depth (ft)	°F	DO (mg/L)	Alkalinity (mg/L)	pH
Surface	78	12.0	103-120	8.8
2	77			
4	76			
5		3.4		
6	75			
8	75			
10	74	0.0		
12	73			
14	71			
15		0.0		
16	67			
18	64			
20	62	0.0		
22	61			
24	59			
25		0.0	171-188	7.0
26	59			
27- bottom	58			

Species and Relative Abundance

Common Name	Number	Percentage	Weight (lb)	Percentage
Gizard Shad	594	34.6	68.79	21.4
Bluegill	575	33.4	47.81	14.9
White Crappie	152	8.9	23.39	7.3
Black Crappie	105	6.1	20.45	6.4
Longear Sunfish	61	3.6	4.11	1.3
Largemouth Bass	54	3.1	48.25	15.0
Channel Catfish	38	2.2	22.78	7.1
Redear Sunfish	34	2.0	4.43	1.4
White Sucker	33	1.9	19.91	6.2
Common Carp	20	1.2	42.18	13.1
Hybrid Sunfish	12	0.7	1.92	0.6
Yellow Bullhead	9	0.5	3.56	1.1
Spotted Sucker	8	0.4	10.72	3.3
Warmouth	8	0.4	0.52	0.2
Golden Shiner	5	0.3	0.74	0.2
Brook Silverside	4	0.2	0.04	<0.1
Black Bullhead	3	0.2	2.25	0.7
Flathead Catfish	1	0.1	0.08	<0.1
Logperch	1	0.1	0.01	<0.1

3) Reservoir Water Quality

A. Brush Creek Reservoir Study, Midwestern Engineers, Inc., 1976

This study, A Study of Brush Creek Reservoir at Muscatatuck State Hospital Butlerville, Indiana included an investigation of the watershed hydrology in relation to future water needs as well as a review of the water supply contract and structures referred to within the contract. Field surveys and investigations were also performed to acquire data in regards to the condition of the dam and reservoir.

Water quality investigations included biological and chemical analysis of the water. Results are summarized in the following table.

Table III-8
Brush Creek Reservoir Study, Midwestern Engineers, Inc., 1976

Parameter	Depths					
	Surface	3-5 Ft.	10 Ft.	15 Ft.	25 Ft.	Discharge Pipe
Temperature °C	23	23	20	15	13	14
Temperature °F	73	73	68	59	55	57
BOD5 (mg/L)	4	3	3	4	17	17
Suspended Solids (mg/L)	2	2	2	2	5	145
Dissolved Oxygen (mg/L)	12	12	11	9	3	2.2
pH	8.3	8.3	8.3	8.3	8.2	8.1
Iron (mg/L)	Tr.	Tr.	0.05	0.15	0.3	2.0
Manganese (mg/L)	Tr.	Tr.	Tr.	Tr.	0.3	0.5
Phosphate (mg/L)	Tr.	Tr.	Tr.	Tr.	0.1	0.5
Nitrate (mg/L)	Tr.	Tr.	Tr.	Tr.	0.05	0.2
Coliform (#/100 ml)	350	400	400	500	50	200

B. Water Supply Study, IU-SPEA, 1983

A report entitled, SOUTHEAST INDIANA WATER SUPPLY STUDY, Water Quality Data and Recommendations, School of Public and Environmental Affairs, Indiana University, 1983 is a portion of work performed for water resources planning. This project was performed for the Division of Water and funded by a General Assembly appropriation in 1979.

Water samples were collected from Brush Creek Reservoir near the outlet structure on the western side of the reservoir at three depths:
BC-1 0.5 meters below the surface
BC-2 middle
BC-3 0.5 meters off the bottom
The appendix of this report included summary sheets for four separate sampling events and this data is represented in the following tables.

Table III-9
Water Supply Study, IU-SPEA, 1983

May 13, 1982	Depth		
Parameter	BC-1	BC-2	BC-3
Temperature °C	22	12.5	9.8
Dissolved Oxygen (mg/L)	11.1	0.1	0.1
pH	8.2	6.8	6.7
Alkalinity (mg/L)	79.5	81.8	90.8
Total P (μg/L)	31.25	65	90
Nitrate-N (mg/L)	1.06	1.08	0.95
Coliform (#/100 ml)	-	-	-
Iron (mg/L)	2.71	2.58	3.97
Manganese (mg/L)	<0.1	0.27	1.38
Color	38	51	83
Odor	1.7	2.0	6.6
Turbidity (NTU)	1.8	7.5	5.2
Secchi depty (cm)	280		

June 14, 1982	Depth		
Parameter	BC-1	BC-2	BC-3
Temperature °C	22	18	12.8
Dissolved Oxygen (mg/L)	7.7	0.3	0.3
pH	7.4	6.9	6.8
Alkalinity (mg/L)	78.4	78.4	92.0
Total P (μg/L)	25.5	58.13	111.25
Nitrate-N (mg/L)	1.35	1.02	1.00
Coliform (#/100 ml)	11700	10500	9700
Iron (mg/L)	0.17	0.49	0.72
Manganese (mg/L)	<0.1	0.33	1.24
Color	45	51	58
Odor	.75	.5	1.25
Turbidity (NTU)	10	19	21
Secchi depty (cm)	105		

August 9, 1982	Depth		
Parameter	BC-1	BC-2	BC-3
Temperature °C			
Dissolved Oxygen (mg/L)			
pH			
Alkalinity (mg/L)	78.4	76.1	127.2
Total P (μg/L)	43.75	82.5	403.75
Nitrate-N (mg/L)			
Coliform (#/100 ml)	16200	19400	17800
Iron (mg/L)	<0.1	<0.1	2.09
Manganese (mg/L)	0.16	<0.1	2.98
Color	32	32	115
Odor	1.0	5.3	12.7
Turbidity (NTU)	10	10	16
Secchi depty (cm)			

October 14, 1982	Depth		
Parameter	BC-1	BC-2	BC-3
Temperature °C	17.5	17.5	13.5
Dissolved Oxygen (mg/L)	1.9	1.1	0.1
pH	7.2	7.3	6.9
Alkalinity (mg/L)	76.11	77.25	115.87
Total P (μg/L)	82	79	808
Nitrate-N (mg/L)	<0.1	<0.1	<0.1
Coliform (#/100 ml)	43000	34000	134000
Iron (mg/L)	<0.1	<0.1	3.0
Manganese (mg/L)	0.6	0.7	5.4
Color	26	26	90
Odor	1.8	2.2	3.2
Turbidity (NTU)	2.4	2.2	7.3
Secchi depty (cm)	200		

4. IDEM Sampling

The Office of Water Management of the Indiana Department of Environmental Management performs sampling and maintains extensive data on surface water quality throughout the State. Donan contacted Mr. Chuck Bell of that office requesting historical data on monitoring locations within the Brush Creek watershed. Mr. Bell responded stating IDEM does have data on Vernon Fork Muscatatuck River. The State does not, however, appear to have historical data on sampling locations within Brush Creek watershed.

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IV. EXISTING WATERSHED CONDITIONS

1. Wetlands

Wetlands occur in and provide benefits to every county in Indiana. The lack of quantitative information on some aspects of Indiana's wetland resources is a major obstacle to improving wetland conservation efforts.

The most extensive database on wetland resources in Indiana is the National Wetland Inventory (NWI) developed by the U.S. Fish and Wildlife Service. In 1985, the IDNR- Division of Fish and Wildlife entered into a cooperative agreement with The U.S. Fish & Wildlife Service to share the cost of mapping Indiana's wetlands. Indiana's NWI maps were produced primarily from interpretation of high-altitude color infrared aerial photographs taken of Indiana during spring and fall from 1980 through 1987. Map production also included field investigations, review of existing information, quality assurance, draft map production, interagency review of draft maps, and final map production.

NWI maps indicate wetlands by type, using the classification system developed by Cowardin et al. (1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.) The minimum wetlands size on NWI maps is generally one to three acres. Very narrow wetlands in stream and river corridors and wetlands that were cultivated at the time of mapping are generally not depicted, and forested wetlands are poorly discriminated.

The most recent and complete analysis of this database was conducted in 1991 by the IDNR. According to the report, Indiana had approximately 813,000 acres of wetland habitat in the mid-1980s when the data were collected and the various types of wetland habitat are summarized below. The extent of wetland loss or gain since that time is unknown.

Table IV-1
Indiana Wetland Habitats

Wetland Habitats	Acres	% of Total
Scrub-Shrub	42,131	5.2
Forested	504,336	62.0
Wet Meadow	55,071	6.8
Shallow Marsh	67,564	8.3
Deep Marsh	20,730	2.5
Open Water	98,565	8.3
Other	24,633	3.0
Total Wetland habitats	813,032	100.0

The best estimate of the wetlands in Indiana prior to settlement 200 years ago is an assessment based on hydric soils (soils that indicate the presence of wetlands) conducted by the USDA Natural Resources Conservation Service (formerly the Soil Conservation Service). Based on an analysis of this data by the IDNR- Division of Outdoor Recreation in 1989, there were approximately 5.6 million acres of wetlands in Indiana 200 years ago. Combining the information from the NWI and the Division of Outdoor Recreation yields the following summary:

• Total land area	23,226,240 acres
• Estimated wetlands circa 1780s	5,600,00 acres
• Percent of surface area in wetlands circa 1780s	24.1%
• Existing wetlands	813,000 acres
• Percent of surface area in wetlands today	3.5%
• Percent of wetlands lost	85%

Nationwide, Indiana ranks 4th (tied with Missouri) in proportion of wetland acreage lost. The vast majority of the 85% of wetlands lost was due to drainage for agricultural production.

The rich, productive soils available as a result of these drainage activities have contributed significantly to the agriculture industry in Indiana. In 1994, Indiana ranked first in the nation in popcorn production, second in spearmint, fourth in soybeans, fifth in corn for grain, and sixth in overall cash receipts.

The report states that Jennings County is in the catergory of Indiana counties having from 3% to 5.9% wetland acreages while Ripley County is in the category having less than 3.0% of the surface area as wetland acreage. The best estimate of the wetlands in the two counties prior to settlement 200 years ago is also an assessment based on hydric soils found in those particular counties. The assessment is based exclusively on the mapping of hydric soils in the Soil Surveys of the respective counties and the Hydric Soils of Indiana listing provided by USDA- Natural Resources Conservation Service (NRCS).

Table IV-2
County Hydric Soils

Jennings County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Bonnie	Bo	Silt loam	590	0.2
Brookston	Br	Silty clay loam	95	0.04
Clermont	Cr	Silt loam	38250	16.0
Peoga	Pe	Silt loam	263	.1
Stendal	Sx	Silt loam	3000	1.2
Wakeland	Wa	Silt loam	6000	.5
Total			**48198**	**20**

Ripley County

Hydric Soil Map Unit	Map Symbol	Soil Texture	Acres	Percent of County Acreage
Cobbsfork	Cm	Silt loam	76856	26.8
Nolin	No	Silt loam	484	0.2
Wakeland	Wa	Silt loam	2649	0.9
Total			**79989**	**27.9**

To date, it appears Ripley County has lost the greatest percentage of wetland habitat based on hydric soil designations. The Clermont silt loam map unit (Ripley County) and the Cobbsfork silt loam map unit (Jennings County) are hydric soils found on the broad nearly flat ridgetops of the Brush Creek watershed. Based soley on the configuration of the landscape, the hydric soils are more prominent in the headwater upland areas of Brush Creek, rather than at the mouth in the natural floodplain areas. The table below indicates that the representation of hydric soils in the watershed (30.3%) is consistent with the percentages represented in the counties as a whole.

Table IV-3
Brush Creek Watershed
Hydric Soils

County	Hydric Soil	Hydric Soil Acreage	% of Watershed	% of Total Hydric Soil Acres
Jennings	Clermont	722	7.8	25.8
	Wakeland	25	0.2	0.9
Ripley	Cobbsfork	2031	22.0	72.7
	Wakeland	17	0.2	0.6
Total		**2795**	**30.2**	**100**

Brush Creek watershed wetlands have been lost or impacted in a variety of ways. The most obvious impact is drainage for agricultural production, however, losses due to residential and commercial development, road building, water development projects, and vegetation removal are also significant. Other activities that may have been contributing factors could include groundwater withdrawal, surface water withdrawal, and water pollution, including sedimentation.

As previously stated, NWI maps indicate wetlands by type including those categories of wetlands that have developed resultant of some activity by man. These wetlands have developed, whether intentionally or unintentionally, in soils that often times involve upland soils as well as hydric soils. Common examples include ponds that are excavated, impoundments created by construction of a dike or dam, and, perhaps the most common, combination structures where soil is incised by excavation and used to construct a dam. Other examples include ditching or fill projects where spoil placement interrupts drainage resulting in wetland habitat.

The NWI maps were relied upon to estimate the acreage of wetlands found in the Brush Creek watershed today. NWI maps are currently available electronically; however, the scale of these drawings are small. To evaluate and quantify wetland acreage within the watershed, drawings were enlarged to measure and compute the total acreages. The majority of the delineations mapped appear to be excavated ponds- typically less than 1 acre in size. The total acreage of all NWI delineations was measured to be 124 acres, which includes ponds and natural wetland areas along streams, etc.

Applying the method used for the State of Indiana above, the best estimate of the wetlands in the Brush Creek watershed prior to settlement 200 years ago is an assessment based on hydric soils (soils that indicate the presence of wetlands) conducted by the USDA Natural Resources Conservation Service. Based on an analysis of the hydric soils mapped in the soil surveys of Jennings and Ripley counties and located in the Brush Creek watershed, there were approximately 2,795 acres of wetlands in the Brush Creek watershed 200 years ago. Combining the information from the NWI and the assessment of hydric soils mapped in the soil surveys yields the following summary:

- Total land area — 9,240 acres
- Estimated wetlands circa 1780s — 2,795 acres
- Percent of surface area in wetlands circa 1780s — 30.2%
- Existing wetlands — 124 acres
- Percent of surface area in wetlands today — 1.3%
- Percent of wetlands lost — 95%

This assessment suggests that wetland loss within the Brush Creek watershed is somewhat greater than the loss experienced Statewide during the same time period.

2. Muscatatuck Development Center

Brush Creek Reservoir is located, in part, on land owned by the Muscatatuck Development Center. The reservoir was built to augment flow of the Vernon Fork Muscatatuck River to provide a water supply for both the City of North Vernon and the Muscatatuck Development Center.

Originally all land surrounding the reservoir was owned by the Development Center however in 1964, land was transferred from the Department of Health to the Department of Natural Resources. The DNR-Division of Fish & Wildlife operate and maintain this area known as the Brush Creek Fish and Wildlife Area. The remainder, which involves 1,841 acres, includes the dam, spillway, and lower portion of the reservoir that remains to be the property of Muscatatuck.

The future of the Muscatatuck Development Center facilities are uncertain. The State of Indiana has announced that there is a plan calling for the closure of Muscatatuck State Developmental Center, housing about 270 people with developmental disabilities, by the end of 2003. There is a great deal of concern in the area about the economic impacts to closure of the facilities, as alternate uses for the facility have not yet presented themselves. The Development Center is the largest employer in the area therefore the loss of jobs is of major concern.

The Development Center has historically operated their own wastewater treatment plant. The effluent from the plant is discharged to the Vernon Fork Muscatatuck River- not Brush Creek.

The grounds owned by the Development Center do not appear to differ from grounds associated with a college campus or a typical suburban area. Runoff from the Development Center facility would be expected to have surface water quality comparable to other residential areas in the watershed.

3. Demographics/ Development Trends

In the period from 1990 through 1997, the State of Indiana grew from 5,544,156 residents to 5,864,108 - an increase of about 5.8%. In the same time period, the two counties, which have part of their area in the Brush Creek watershed, experienced growth of 12.7%. From 1990 to 1997, Jennings County increased 15% while Ripley County's population grew 10.4%.

Projections into the future predict that from the 1997 estimate to the year 2020, the two counties will have population growth of nearly 10,000 residents which is an increase of >18%. In the same time period, the rate of increase projected for the State of Indiana is approximately 10%. Since only portions of the two counties are within the watershed of Brush Creek, it does not necessarily follow that the population of Brush Creek watershed will increase at the rates predicted for the entire counties. The reader is cautioned therefore, that this data should only be relied upon to predict trends in development.

Table IV-4
Population Projections
of Counties in
Brush Creek Watershed

County	Census	Estimate	Projections				
	1990	1997	2000	2005	2010	2015	2020
Indiana	5,544,156	5,864,108	6,044,528	6,215,296	6,318,404	6,404,070	6,481,489
Jennings	23,661	27,217	29,025	30,736	31,769	32,628	33,404
Ripley	24,616	27,177	28,289	29,342	29,977	30,506	30,983
Total	48,277	54,394	57,314	60,078	61,746	63,134	64,387

Historical information was compiled at the township level for Brush Creek watershed. Table IV-5 shows that the Ripley County component (Otter Township) of the watershed had the greatest rate of growth for the period from 1990 to 1996. This limited information is not sufficient for predicting future township or watershed population growth. Rather, this information is presented as a basis for establishing trends and patterns of development for the areas of the watershed.

Table IV-5
Population Changes
for Townships in
Brush Creek Watershed

County/Township	Population			Percent Change	
	1960	1990	1996	1960-90	1990-96
Jennings	17,267	23,661	26,747	37.03	13.04
Campbell	2,919	1,790	1,568	-38.68	-12.4
Columbia	751	813	801	8.26	-1.48
Ripley County	20,641	24,616	26,932	19.26	9.41
Otter Creek	1,326	1,334	1,462	0.6	9.6

4. Recreational Use

Brush Creek Reservoir is used predominantly for fishing as motorized watercraft is prohibited. An exception to this policy is a provision to allow pontoon boats owned and operated by the Muscatatuck Development Center. The center uses the pontoon boats for occasional boat rides as recreation for the residents of the Center. Beyond that, motorized boats are not allowed.

The public access ramp on the south side of the reservoir is used for small watercraft launching. There is some fishing from the shoreline however most anglers fish from boats or canoes.

5. Land Use

The term "land use" often is associated with zoning, which denotes a method used by regional planners to divide an area into districts in which certain activities are permitted. The land use description or categorization identifies the principal activity-taking place in such districts or aerial units. Although zoning or divisions of areas according to the primary activity originally had little relationship to water quality, it has been realized that water quality loadings from nonpoint sources can, to a certain degree, be correlated with land use and intensity of land use activities. An example of such a correlation is seen in Figures IV-1 & IV-2.

Figure IV-1 Regional relationship between land use and annual average stream export of total nitrogen East and central general farming and forest region (From Omernik)

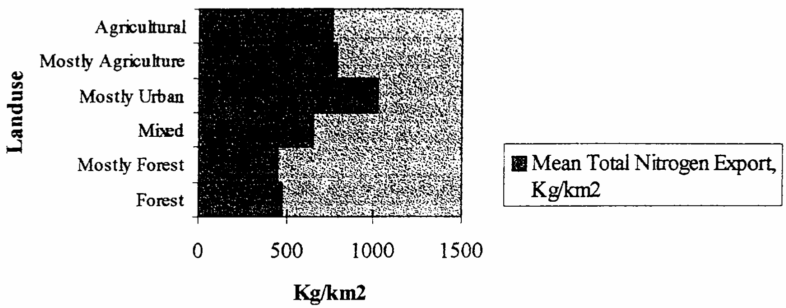
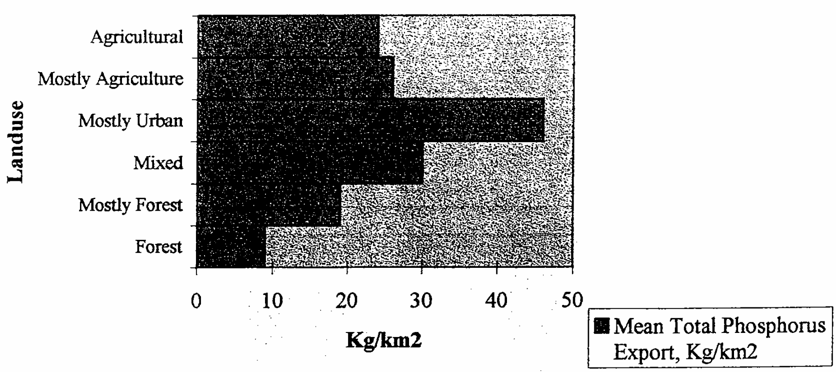


Figure IV-2 Regional relationship between land use and annual average stream export of total phosphorus East and central general farming and forest region (From Omernik)



The problem of land use and its effect on water quality is generally associated with urban and agricultural developments. Spreading urban and uncontrolled streamside developments can result in deterioration of water quality. Impervious streets, roofs, and other areas increases runoff coefficients and even small rains are capable of washing accumulated pollutants into surface waters. Failed on-site septic systems associated with unsewered residential development are an additional source of elevated pollution loading to a stream.

In rural areas, animal barnyards and feedlots as well as conventional tillage on highly erodible lands can produce high sediment and nutrient loading, especially if overfertilization is prevalent. The pollution loading potential of land use activities then, can be classified into three categories:

1. Land not in need of control, including unmanaged forestland and idle permanently vegetated open land.
2. Land sometimes needing control measures such as pasture, hayland, and in particular, cropland.
3. Land usually requiring control measures; typical examples are some urban areas with residential, commercial, and industrial areas, mining operations, construction sites, and animal feedlots. These land use activities generally are considered to be the most threatening to water quality.

Brush Creek watershed as a whole would most likely compare with the "mostly agriculture" category presented in Figures IV-1 & IV-2. Figures IV-3, IV-4, & IV-5 show proportions of watershed land use per county and for the watershed as a whole. It appears that the portion of the Brush Creek watershed that is in Ripley County is more representative of the watershed than the watershed acreage found in Jennings County. This is due to the fact that nearly half (45.4%) of the Jennings County portion of the watershed is forestland.

Figure IV-3
Brush Creek Watershed Landuses
Jennings County

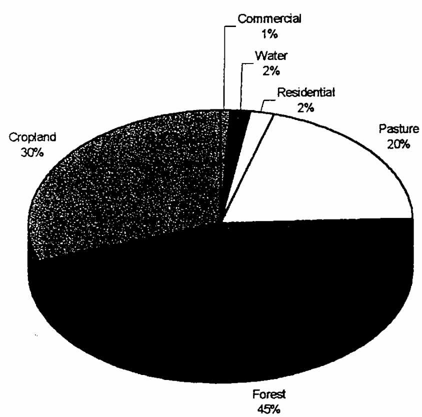


Figure IV-4
Brush Creek Watershed Landuses
Ripley County

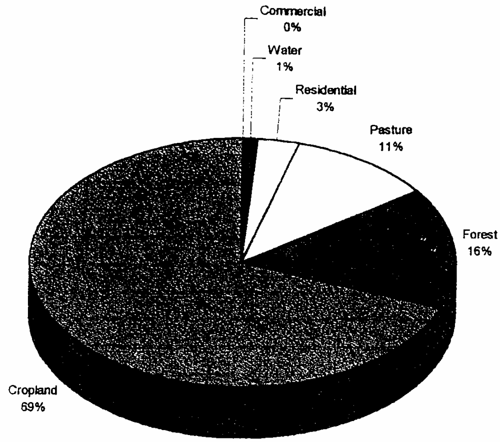
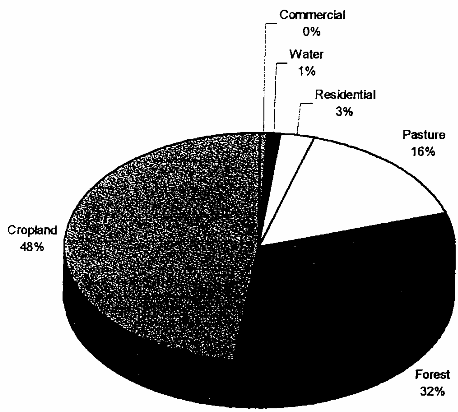
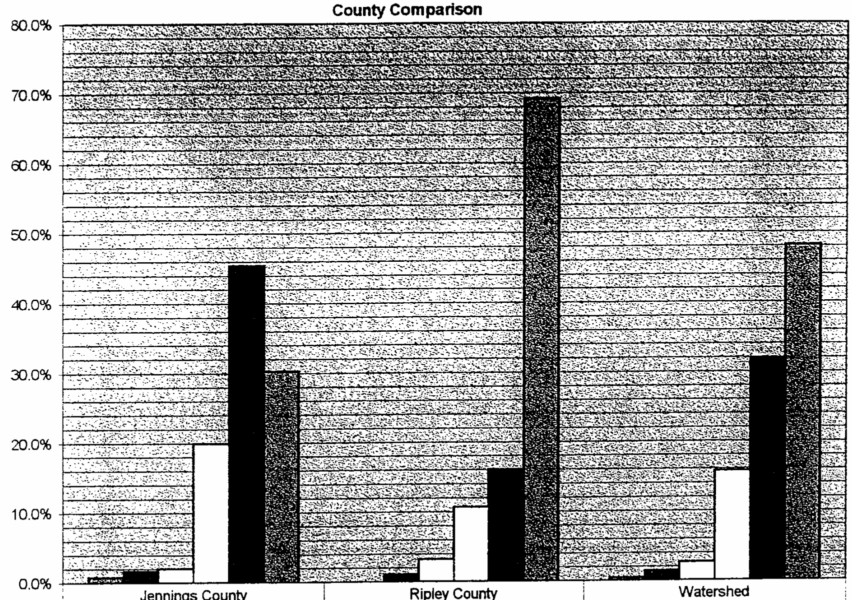


Figure IV-5
Brush Creek Watershed Landuses



The size of the watershed prohibited the mapping of land uses on a field-by-field basis. Instead, a map was generated electronically, which identifies general categories of land use on a broader basis. Figure IV-7, the land use map for the Brush Creek watershed was generated from satellite imagery and topographic maps. Mapping was spot verified or "ground proofed" by visual field checks. The table in Figure IV-7 shows the land use of the watershed in acres and the acreages as a percentage of the total area represented in Figure IV-6. The table in Figure IV-7 also summarizes the land use categories by county subwatershed.

Figure IV-6
Brush Creek Watershed Landuses
County Comparison

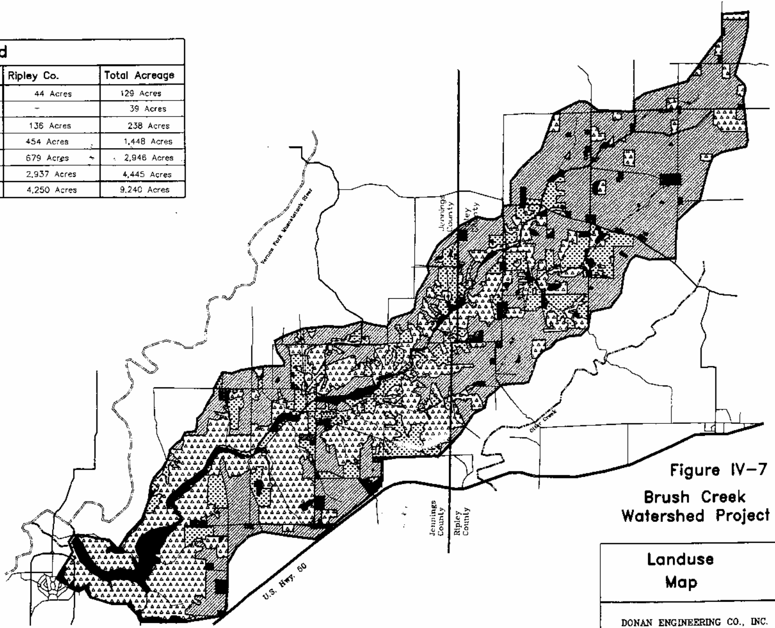


	Jennings County	Ripley County	Watershed
Commercial	0.8%	0.0%	0.4%
Water	1.6%	1.0%	1.3%
Residential	2.0%	3.2%	2.6%
Pasture	19.9%	10.7%	15.7%
Forest	45.4%	16.0%	31.9%
Cropland	30.2%	69.1%	48.1%

Studies of non-point source pollution tend to focus on identifying and quantifying non-point source loads associated with various land uses. However, landform characteristics can have a greater impact on the extent of non-point sources pollution than the land use. As an example, the watershed located in Ripley County has extensive areas of land used exclusively for row crop

Legend

Land Uses	Jennings Co.	Ripley Co.	Total Acreage
Water	80 Acres	44 Acres	129 Acres
Commercial	39 Acres	–	39 Acres
Residential	102 Acres	136 Acres	238 Acres
Pasture	994 Acres	454 Acres	1,448 Acres
Forest	2,267 Acres	679 Acres	2,946 Acres
Cropland	1,508 Acres	2,937 Acres	4,445 Acres
Total Acreage	4,990 Acres	4,250 Acres	9,240 Acres



Scale: 1"=4000'

Figure IV-7

Brush Creek Watershed Project

Landuse Map

DONAN ENGINEERING CO., INC.
4342 North US 231
Jasper, IN 47546
(812) 482-5611

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production with conventional tillage. A large percentage of those areas are predominantly prime farmland areas having 0 to 2 percent slopes. While the Jennings County portion of the Brush Creek watershed does have significant prime farmland, the majority of the forested watershed would not support an agricultural enterprise of continuous corn production- both from an economic and ecological perspective. There is not a predetermined combination of land uses that are appropriate for a watershed. The concerns of nonpoint source pollution have to do more with selecting a land use appropriate for the landform available.

A. Land Use Categories

The term land use describes the prevailing activity taking place in an essentially uniform demographic area. Lands classified into a single land use category may be quite diversified with regard to topography, soil types, slope, and other important factors. Therefore, wide variability in potential pollutant loading within a single land use category should be expected.

Land use categories for the Brush Creek watershed are divided into generally rural and urban types. Urban types include residential and commercial uses. The rural connotation refers to forest, open water and wetlands, cropland and pastureland. Detailed land use inventories often recognize as many as 50 categories and sub-categories. Due to the wide variations in pollutional loadings within each land use category, it is not possible to estimate pollution impact for each detailed land use category. For watershed pollution studies, land uses are grouped together into more general categories, which bear a certain distinct relationship to generation of pollutants.

Land use is a simple term describing the prevailing activity occurring in an area and, as such, it bears little relationship to pollution generated from that area. Although the activity per se may produce some pollution directly, many other factors must be considered in predicting pollution-loading rates. If one intends to trace the origin and causes of the pollution, the land use activity description loses its meaning, and more meaningful factors such as dust and dirt accumulation rates on impervious areas, soil type and slope, vegetative cover, atmospheric deposition, etc. are more closely related to the pollutant loading. A partial list of factors that determine pollutant loadings from aerial sources and their relation to land uses are listed as follows:

Factors strongly effecting pollution generation and correlated closely with land uses.

- Population density
- Atmospheric fallout
- Degree of impervious surface (usually correlated with population density)
- Vegetative cover
- Street litter accumulation rates
- Traffic density
- Curb density and height
- Street cleaning practices
- Pollution conveyance systems

Factors strongly effecting pollution generation but correlated poorly with land uses.

- Street surface conditions

- Degree of impervious area directly connected to a channel
- Delivery ratio
- Surface storage
- Organic and nutrient content of soils

Factors strongly effecting pollution generation but unrelated to land uses

- Meteorological factors
- Soil characteristics and composition
- Permeability
- Slope
- Geographical factors

From this list of causative factors it can be seen that many are, in part, correlated to land use. Therefore, attempts to relate pollution loadings from diffuse sources to land use are justified. Factors not related to land use such as slope, soil texture and fertility, drainage density, and vegetative cover are less dominant for urban lands, which primarily have impervious surfaces, than for rural lands. Therefore, it is often easier to relate pollutant generation to land use for urban settings.

Despite its questionable accuracy, the concept of relating pollution loading to land use categories has found wide application in aerated pollution abatement efforts and planning. A simple reason explains this situation; the concept provides a simple mechanism and quick answers to pollutant problems of large areas where more complicated efforts would fail because of the enormous amounts of information required. The land use/pollutant loading concept also is compatible with so-called "overview modeling", whereby unit loadings are combined with information on land use and soil distribution, and other characteristics to yield watershed loadings, or identify areas producing the highest amount of diffuse pollution.

1. Residential land use.

This term applies to a wide variety of urban sections, ranging from subdivisions with 1-acre lots to highly congested urban centers. Residential zones typically are subdivided according to population density into low-density (1 to 6 people/acre), medium density (7 to 20 people/acre) and high-density areas (>21 people/acre). Within the Brush Creek watershed, the only area regarded as a population center and having a wastewater treatment facility is the Muscatatuck Development Center. Therefore, residential areas are comprised of building lots large enough to at least accommodate some sort of on-site septic system. As that is the case, the residential areas, both within the borders of platted towns and outside in rural settings, are low-density areas.

In general, low density, well-maintained residential areas with natural surface runoff drainage systems generate pollutant loadings that are of the same order of magnitude as background loadings from nonagricultural rural lands. However, the on-site septic systems may add significant amounts of pollutants, especially to base flow components. Streams draining low-density residential areas served by septic systems generally have higher nitrogen contents.

production with conventional tillage. A large percentage of those areas are predominantly prime farmland areas having 0 to 2 percent slopes. While the Jennings County portion of the Brush Creek watershed does have significant prime farmland, the majority of the forested watershed would not support an agricultural enterprise of continuous corn production- both from an economic and ecological perspective. There is not a predetermined combination of land uses that are appropriate for a watershed. The concerns of nonpoint source pollution have to do more with selecting a land use appropriate for the landform available.

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- Traffic density
- Curb density and height
- Street cleaning practices
- Pollution conveyance systems

Factors strongly effecting pollution generation but correlated poorly with land uses.

- Street surface conditions

2. Commercial land use.

This category covers a broad scale of land use activities that include shopping centers, warehouse storage areas, parking areas, congested downtown commercial zones, and governmental buildings. Within the Brush Creek watershed, the areas mapped as commercial land use represent the buildings and surrounding grounds of the Muscatatuck Development Center. The Center is located on the watershed divide such that the majority of the Center is outside the Brush Creek watershed.

The degree of imperviousness of commercial areas is generally medium to high but is believed to be low to medium within this watershed. The buildings, roads, and parking lots are all impervious however the lawn areas still comprise most of the area.

Studies from the Pollution from Land Use Activities Reference Group indicated pollution loading from commercial land in the following ranges:

Table IV-6
Pollution Loading-Commercial Landuse

Parameter	lb./acre/year
Suspended Solids	45-750
Total Phosphorus	0.1-0.35
Total Nitrogen	1.7-10
Lead	0.15-1.0

3. Cropland

The land use mapping identifies four map units that are rural including cropland, pasture land, forest, and open water/wetland areas.

Many factors effect pollutant discharge from farm croplands. Pollutants arise from surface runoff by erosion of topsoil and recently surface applied chemicals, through interflow, which is tile drainage water, and groundwater base flow. Often the reduction of one component of pollution results in an increase in other components. Erosion and soil loss by surface runoff is considered a predominant source of pollution from croplands. The disturbing activity associated with tillage substantially increases the erosion potential of croplands. On the other hand, increased hydrologic surface storage and permeability of tilled fields reduce hydrologic activity, which sometimes balances the increased erosion potential.

Regarding the nutrient loss of N and P, over 90% is associated with soil loss. Nutrient losses usually represent only a small fraction of the applied fertilizer and often are economically insignificant. Nevertheless, their pollution impact almost always exceeds the standards accepted for preventing accelerated eutrophication of surface waters. Table IV-7 shows that even at the conservative end of predicted ranges, loading of nitrogen, phosphorus, and suspended solids can be significant.

Table IV-7
Ranges of Non-point Source Pollutant Loads by Land Use
(lb/acre/year)
(Source: Sonzogni etal, 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen
Rural			
Cropland	18-4550	0.18-4.1	3.8-28
Improved Pasture	27-71	0.1-0.4	2.9-12.5
Forest	1-730	0.02-0.6	1-5.6
Idle	6-730	0.02-0.6	0.4-5.4
Urban			
Residential	550-2050	0.4-1.2	4.5-6.5
Commercial	45-740	0.1-0.8	1.7-9.8
Industrial	400-1517	0.8-3.7	1.7-12.5
Developing urban	24,500	20	56

4. Pasture land

Pasture used directly for livestock production and grazing practices include continuous and seasonal or rotational grazing. Unit loads of most pollutants from pasture are at least an order of magnitude less than loads from cropland areas. Generally, pastures are considered nonhazardous land uses requiring little or no pollution control. When cattle are allowed close proximity or access to a watercourse however, pasture may become a pollution hazard.

Renovation practices on pastures, including mechanical and chemical methods, improve grass quality and density, and reduce soil loss. Converting hazardous agricultural lands to pasture may be a possible control strategy.

5. Forest

Undisturbed forest or woodland represents the best protection of lands from sediment and pollutant losses. Woodlands and forests have low hydrologic activity due to high surface water storage and interception in leaves, soil, mulch, and surface roughness. Furthermore, forest soils frequently have improved permeability. Even lowland forest with a high groundwater table absorbs large amounts of precipitation and actively retains and retard runoff. In addition, tree canopy and ground covers reduce surface impact and encourage infiltration. The increased organic content of forest soils significantly reduces erosion losses such that surface runoff from forested areas is often almost nonexistent.

Streams draining lowland forests, however, may have elevated organic and nutrient levels caused by leaching from soils by interflow and base flow. Despite this effect, woodlands are generally regarded as the determinants to background pollution levels against which other land uses are judged.

Uncontrolled logging operations, including clear cutting, often disturb the forest's resistance to erosion. In many situations, almost all sediment reaching waterways from forestlands originates from construction of logging roads and/or from clear cuts. Logging roads that disrupt or infringe upon natural drainage channels are primary sources of sediment.

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V. STREAM ANALYSIS

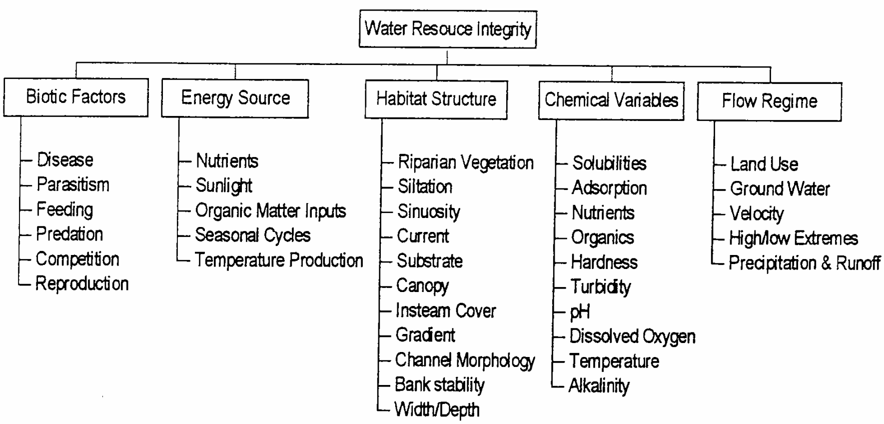
A stream is a complex ecosystem in which several biological, physical, and chemical processes interact. Changes in any one characteristic or process have cascading effects throughout the system and result in changes to many aspects of the system.

Some of the factors that influence and determine the integrity of streams are shown in Figure V-1. Often times several factors can combine to cause profound changes. For example, increased nutrient loading alone may not cause a change to a forested stream, however, when combined with tree removal and channel widening, the result can shift the energy dynamics from an aquatic biological community based on leaf litter inputs to one based on algae and macrophytes.

Many stream processes are in a delicate balance. Hydrologic changes, for example, that increase stream flow, if not balanced by greater channel complexity and roughness, result in flow that erodes banks or the stream bottom. Increases in sediment load beyond the transport capacity of the stream, on the other hand, leads to deposition, lateral channel movement into streambanks, and channel widening.

Most systems would benefit from increased complexity and diversity in physical structure. Structural complexity is provided by trees falling into the channel, overhanging banks, roots extending into the flow, pools and riffles, overhanging vegetation, and a variety of bottom materials. This complexity enhances habitat for organisms and also restores hydrologic properties that often have been lost.

Figure V-1
Factors that Influence the Integrity of Streams

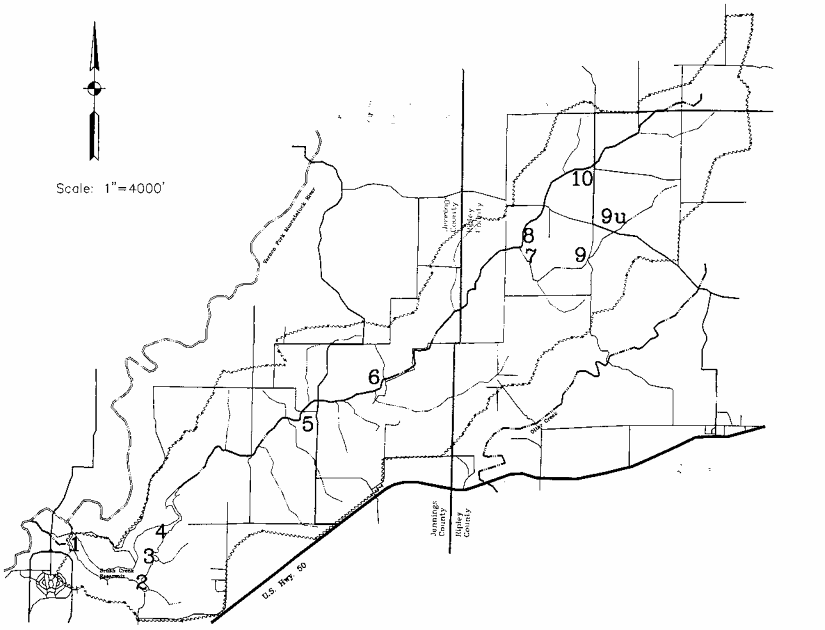


1. Methods

Characterization of the water quality of Brush Creek was performed in accordance with established guidelines recommended by the Lake and River Enhancement Program. Ten sampling points were selected including four within the reservoir and six at various points of within Brush Creek proper and at the mouths of significant subwatersheds as shown in Figure V-2. These points were selected by the consultant in concert with Natural Resources personnel at the State and Federal level (including Division of Water personnel and local Soil and Water Conservation District personnel). There were seven named tributaries and three sites located within Brush Creek selected to represent water quality in the watershed. These locations were selected based on historical and current conditions in the various subwatersheds, the proportion of the Brush Creek watershed represented by the tributary, and county boundaries. The following table summarizes the significant features of each of the sampling locations.

Table V-1
Brush Creek Reservoir/Watershed
Sampling Locations

Sample Point	Location	Quadrangle	County	Representing
1	Dam area of Reservoir	Butlerville	Jennings	Lake Pool
2	South inlet of Reservoir	Butlerville	Jennings	Sediment loading at public access boat ramp
3	Southeast inlet of Reservoir	Butlerville	Jennings	Unnamed tributary of Brush Creek, F&W area, and private land
4	Main inlet of Reservoir	Butlerville	Jennings	Brush Creek watershed
5	Brush Creek	Holton	Jennings	Cattle in stream, middle watershed
6	Brush Creek	Holton	Jennings	Background to cattle in stream, middle watershed.
7	Unnamed Tributary	Holton	Ripley	1,400 acre subwatershed
8	Brush Creek	Holton	Ripley	Upper watershed
9	Unnamed Tributary	Holton	Ripley	Intensive agricultural land, upper area of subwatershed.
10	Brush Creek	Holton	Ripley	Intensive agricultural land, upper watershed.



Sample Point	Location
1	Dam Area
2	Boat Ramp
3	East Inlet
4	Main Inlet
5	Brush Creek
6	Brush Creek
7	Unnamed Tributary
8	Brush Creek
9	Unnamed Tributary
9u	Upgradient of 9
10	Brush Creek

Figure V–2

Brush Creek Watershed Project

Sample Points Location Map

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4342 North US 231
Jasper, IN 47546
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At each site, data on water quality was collected and analyzed according to the recommended parameters. A duplicate sample was also analyzed in the laboratory to validate the consistency of detected levels of the various contaminants. This sample was a replicate of sample 5 and was identified as sample 11.

2. Chemical & Physical Quality

At each of the ten sites, water chemistry was evaluated during a rain event on June 6, 2001 and as base flow on samples collected on August 8, 2001. Physical and chemical water quality parameters included:

- pH
- Conductivity
- Temperature
- Dissolved Oxygen
- Ammonia N
- Total Kjeldahl Nitrogen (TKN)
- Nitrite N
- Organic N
- Total N
- Total Phosphorus
- Dissolved Phosphate
- Turbidity
- Flow

Base flow stream sampling included measurements of the common chemical and physical parameters as well as nutrient levels. This provides a comprehension of typical or base conditions in Brush Creek, its tributaries and inlets to the reservoir. Table V-2 presents base flow conditions.

Storm flow was performed after a spring rain event. The Applied Meteorology Group of Purdue University reports 0.71 inches of rain on June 5, 2001 and 0.49 inches on June 6, 2001 for North Vernon, Indiana. The following table summarizes water quality data to represent runoff from that rain event.

Table V-2
Base Flow

Reservoir

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
1	Pool	8.67	247	31.7	138	10.1	<0.10	1.5	0.026	1.5	1.526	0.08	<0.05	7.8
2	Boat Ramp	8.6	239	34.3	113	8.01	<0.10	1.2	<0.020	1.2	1.2	0.065	<0.05	11
3	East Inlet	8.68	256	34.8	115.9	8.6	<0.10	1.3	<0.020	1.3	1.3	0.091	<0.05	12
4	Brush Creek Inlet	8.58	302	34.2	122	8.55	<0.10	1.5	<0.020	1.5	1.5	0.14	<0.05	18

Brush Creek

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
5	Lower watershed	7.75	447	25.2	67	5	<0.10	0.82	0.24	0.82	1.06	0.059	<0.05	6
6	Mid watershed	7.77	415	24.7	75.6	6.2	<0.10	0.57	0.11	0.57	0.68	<0.05	<0.05	2
7	Lower south fork	7.9	535	28.2	123.4	9.62	<0.10	0.43	0.3	0.43	0.73	<0.05	<0.05	2.3
8	Lower north fork	7.8	522	25.1	90.6	7.38	<0.10	0.49	1.4	0.49	1.89	0.052	<0.05	4.3
9	upper south fork	7.7	560	28.9	23.2	1.76	0.36	1.6	0.25	1.24	1.85	0.2	<0.05	34
9U	9 backgound	7.7	530	28	89	6.8	<0.10	0.96	0.26	0.96	1.22	0.12	<0.05	2.2
10	upper north fork	7.68	492	25.8	85.1	6.3	<0.10	0.99	0.49	0.99	1.48	0.086	0.052	19
11	Duplicate 5	7.75	451	25.1	70	5.1	<0.10	0.85	0.24	0.85	1.09	0.054	<0.05	5.4

Table V-3
Storm Sampling

Reservoir

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
1	Pool	7.96	335	22.5	98.8	8.65	0.16	1.1	0.26	0.94	1.36	0.053	<0.050	3.29
2	Boat Ramp	7.85	343	21	113	9.59	0.16	1.1	0.472	0.94	1.572	0.066	<0.05	10.5
3	East Inlet	8.01	329	22.5	104	8.7	0.18	0.82	0.321	0.64	1.141	<0.050	<0.05	4.18
4	Brush Creek Inlet	7.93	336	21.3	86	8.28	0.31	2.6	3.4	2.29	6	0.43	0.088	177

Brush Creek

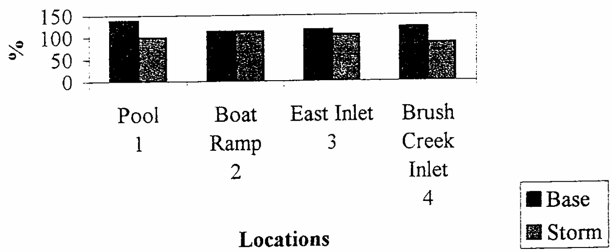
Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
5	Lower watershed	7.73	358	20	90	8.3	0.46	2.4	4.3	1.94	6.7	0.35	0.12	160
6	mid watershed	7.6	377	19.5	89.7	8.2	0.3	2.1	3.8	1.8	5.9	0.37	0.099	103
7	lower south fork	7.6	410	22	78	6.8	0.27	1.9	1.9	1.63	3.8	0.33	0.14	38.8
8	lower north fork	7.6	393	22	86	7.9	0.3	2.3	2.4	2	4.7	0.31	0.13	44.7
9	upper south fork	7.6	383	23	85	7.8	0.22	2.3	1.942	2.08	4.242	0.27	0.11	48.1
10	upper north fork	7.5	388	23	79	6.9	0.32	2.5	5.1	2.18	7.6	0.31	0.12	51
11	Duplicate 5	7.75	349	20	91	8.3	-	-	-	-	-	-	-	-

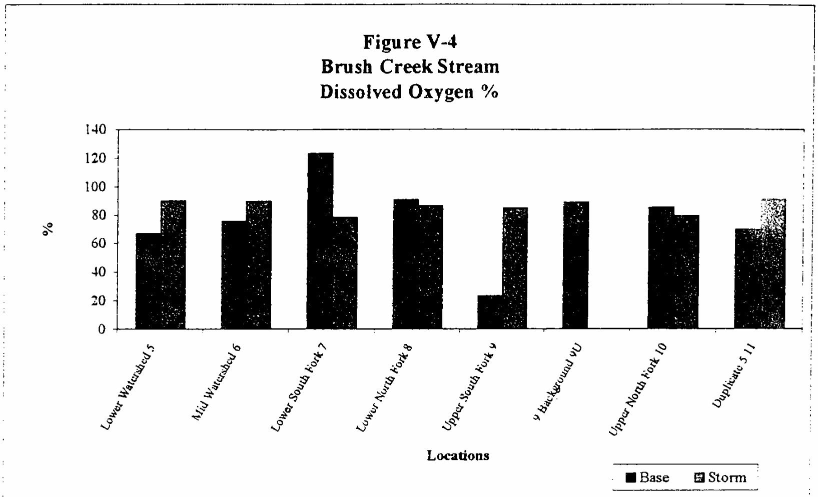
The pH, Conductivity, Temperature, and Dissolved Oxygen were measured as field parameters. An Oakton® DO-100 Dissolved Oxygen Meter and an Oakton® pH/Con 10 meter were used to determine the field parameters. All other parameters were laboratory tested. Samples were placed into appropriate containers with preservatives (if needed) and stored in ice chests until delivered to the laboratory. All sampling techniques and laboratory analytical procedures and methods were performed in accordance with *Standard Methods for the Examination of Water and Wastewater, 17th Edition* (APHA, 1989).

A. Dissolved Oxygen

Dissolved Oxygen (DO) is the measure of the amount of life-sustaining oxygen dissolved in the stream water and, therefore, available to fish, invertebrates, and all other organisms living in the stream. The higher the level of DO, the more variety of life the stream can support. DO then, is arguably the most important parameter of water for aquatic organisms. Most organisms need oxygen to fuel the chemical reactions involved in respiration.

Figure V-3
Brush Creek Reservoir
Dissolved Oxygen %





The absence of oxygen is often a sign of severe pollution within the stream. Different species of organisms have different DO requirements. Only a few are able to live in low concentrations such as carp, catfish, and bloodworms. Most sport fish species suffer if DO concentrations fall below a concentration of 3-4 mg/L. Larvae and juvenile fish are more sensitive and require even higher levels. Many fish and other aquatic organisms can recover from short periods of low DO in the water. However, prolonged episodes of depressed DO concentrations of 2 mg/L or less can result in dead waterbodies. Prolonged exposure to low DO conditions can suffocate adult fish or reduce their reproductive survival by suffocating sensitive eggs and larvae. In addition, low DO can starve fish by killing aquatic insect larvae and other prey. Low DO concentrations also favor anaerobic bacteria that produce the noxious gases or foul odors often associated with polluted waterbodies.

Water absorbs oxygen directly from the atmosphere, and from plants as a result of photosynthesis. The ability of water to hold oxygen is influenced by temperature and salinity. Water loses oxygen primarily by respiration of aquatic plants, animals, and microorganisms. Due to their shallow depth, large surface exposure to the atmosphere, and constant motion, streams generally contain abundant DO. However, external loads of oxygen-demanding wastes or excessive plant growth induced by nutrient loading followed by death and decomposition of vegetative matter can deplete oxygen. When organisms die, their tissues will decompose through the process of aerobic respiration, which requires oxygen. This process removes oxygen from the aquatic ecosystem. Therefore, a large influx of organic matter into a stream can greatly decrease the amount of oxygen that is available to organisms, possibly causing periods of die-off. This process, referred to as biochemical oxygen demand, can compound itself as lowered DO levels lead to die-off which further reduces the DO level resulting in a cyclic effect.

Any loading of organic material from a watershed to a stream results in an oxygen demand. Excess loads of organic material may arise from a variety of land use practices, combined with storm events, erosion, and washout. Some agricultural activities, particularly large-scale animal operations and improper manure application, can result in significant BOD loads- reducing DO concentrations. Land-disturbing activities of silviculture and construction can result in high organic loads through the erosion of organic topsoil. Runoff from residential areas often times is loaded with high concentrations of organic materials derived from a variety of sources.

Figure V-5
Brush Creek Reservoir
Dissolved Oxygen Concentrations

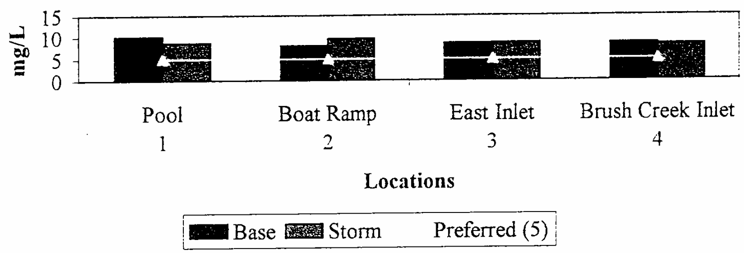
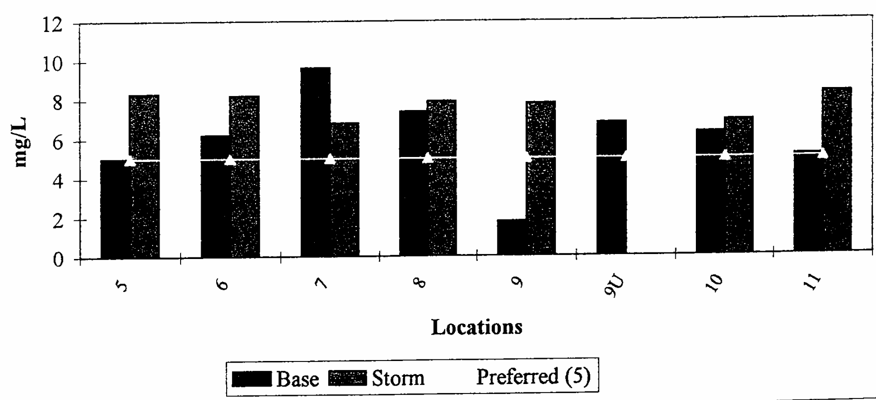


Figure V-6
Brush Creek Stream
Dissolved Oxygen Concentrations



B. pH

Alkalinity, acidity, and buffering capacity are important characteristics of water that effect its suitability for aquatic life and influence chemical reactions. The acidic or alkaline nature of water is commonly quantified by the negative logarithm of the hydrogen ion concentration, or pH. A pH value of 7 represents a neutral condition; a pH of less than 5 indicates moderately acidic conditions; a pH greater than 9 indicates moderately alkaline conditions.

Many biological processes, such as reproduction, cannot function in acidic or alkaline waters. In particular, aquatic organisms may suffer an osmotic imbalance under sustained exposure to low pH waters. Rapid fluctuations in pH also can stress aquatic organisms. Finally, acidic conditions also can aggravate toxic contamination problems through increased solubility, leading to the release of toxic chemicals stored in stream sediments. Stream water in the Brush Creek watershed tends to be somewhat alkaline.

Figure V-7
Brush Creek Reservoir pH

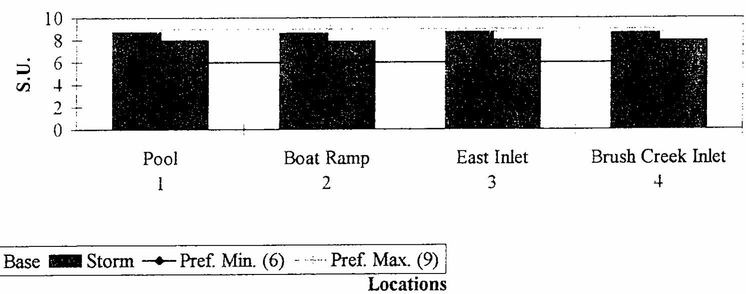
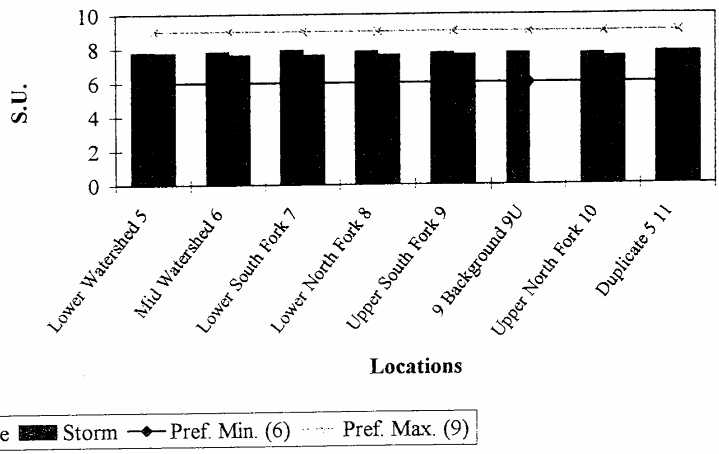


Figure V-8
Brush Creek Stream pH



C. Conductivity

Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions and their concentration dissolved in the solution. Conductivity in a sense then is an indirect measure of the total dissolved solids in a stream. Conductivity measurement in mS/m can generally be multiplied by 0.625 to obtain an equivalent dissolved solids concentration in mg/L. These dissolved solids include salts, some organic materials, and a wide range of other things from nutrients to toxic substances.

Both high and low concentrations of dissolved solids can negatively impact a stream; however, dissolved ions of nutrients are important for growth of organisms. Dissolved ions can include calcium, bicarbonate, nitrogen, phosphorus, iron, and sulfate. High concentrations can have a laxative effect and result in poor tasting water. In addition, dissolved solids include things that are both good and bad for living organisms. Surface water quality standards (industrial) have been set at 750 mg/L for Indiana and that level is used as the target for this study. The equivalent conductivity value is 1200 mS/m.

Figure V-9
Brush Creek Reservoir Conductivity

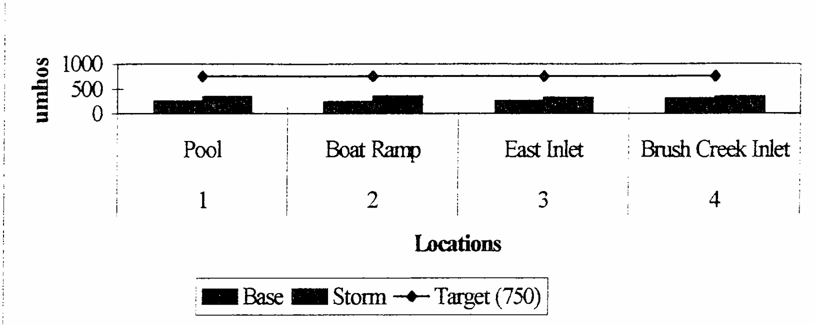
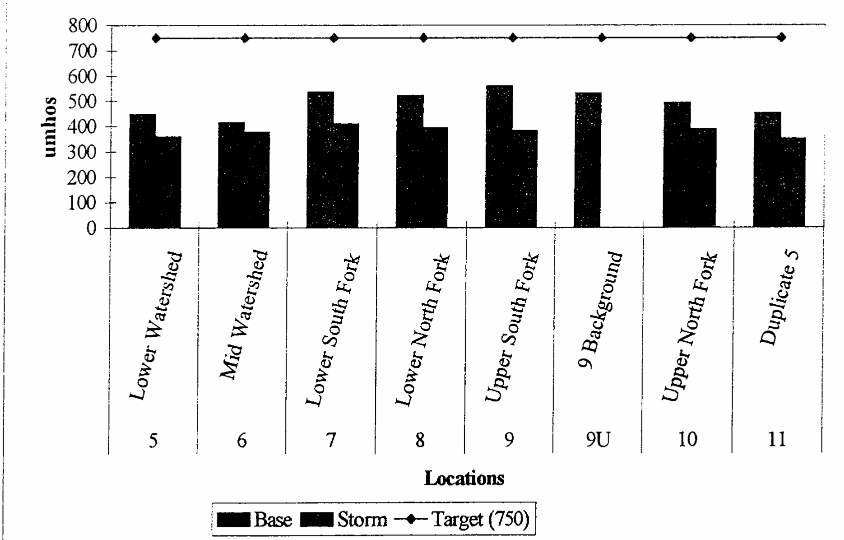
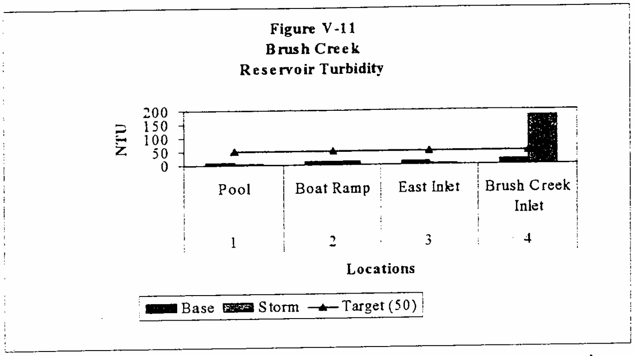


Figure V-10
Brush Creek Stream Conductivity

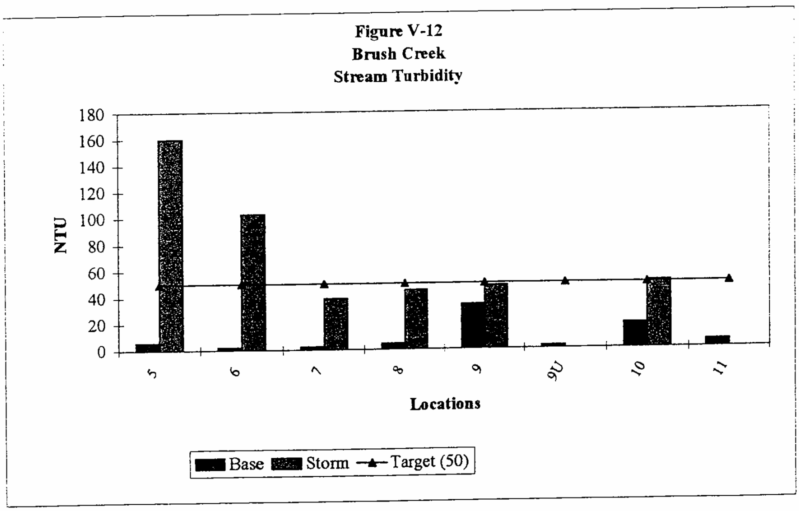


D. Turbidity

Turbidity is a measure of the dispersion of light in a column of water due to various things suspended in the water. These suspended materials include soil colloids and other non-living things, as well as algae and other small forms of life.



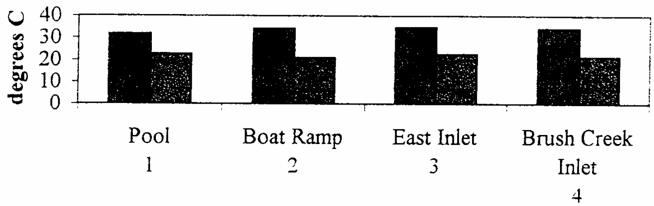
The criteria for turbidity in surface waters is <50 NTU for the protection and propagation of warm water fish and other organisms. The effects of too much turbidity include a decline in the diversity of aquatic organisms. This is due in part to temperature increases with higher turbidity, which results in lowered dissolved oxygen. Other effects include decreased photosynthesis due to reduced light penetration. The suspended matter also can clog fish gills causing die-off.



E. Temperature

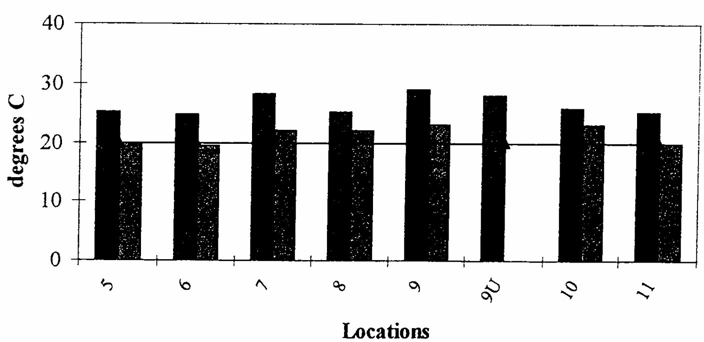
Water temperature (measured in °C) is a crucial factor in a stream ecosystem for a number of reasons. First, dissolved oxygen solubility decreases with increasing water temperature, therefore the stress imposed by oxygen-demanding waste increases with higher temperature. Second,

Figure V-13 Brush Creek Reservoir Temperatures



temperature governs many biochemical and physiological processes in cold-blooded aquatic organisms, and increased temperatures can increase metabolic and reproductive rates throughout the food chain. Third, many aquatic species can tolerate only a limited range of temperatures, and shifting the maximum and minimum temperatures within a stream can have profound effects on

Figure V-14 Brush Creek Stream Temperatures



species composition. Finally, temperature also affects many abiotic chemical processes, such as reaeration rate, sorption or organic chemicals to particulate matter, and volatilization rates. Temperature increase can lead to increased stress from toxic compounds, for which the dissolved fraction is usually the most bioactive fraction. The criteria for temperature in surface waters for the protection and propagation of cold water fish and other organisms is <20 °C.

F. Nitrate Nitrogen

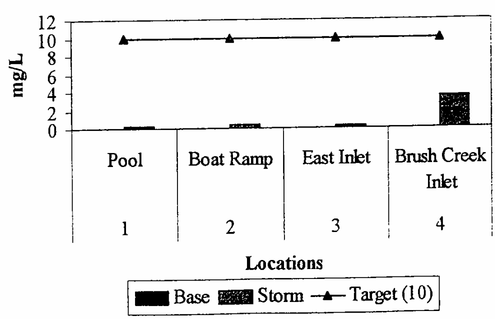
Nitrate concentration is a measure of the oxidized form of nitrogen in the stream water, which is the basic building block for proteins. Nitrates are directly useable by living organisms, and are an essential macronutrient in an aquatic ecosystem.

A healthy aquatic ecosystem should not have too many or too few nitrates. The usual circumstance is too many nitrates, which can result in too much algae and fast aquatic plant growth. Eventually this results in an abundance of decaying organic material, which depletes dissolved oxygen levels. The end result is reduced diversity and a lower quality of life for aquatic organisms.

Nitrite nitrogen is an intermediate form of nitrogen in the cycle. In the most basic concept, the cycle begins when fish eat and excrete ammonia. The ammonia is toxic to fish and must be removed or changed to a harmless form. Bacteria consume the ammonia and excrete nitrite, which is also toxic to fish. Another type of bacteria consumes the nitrite and excrete nitrate. Nitrate, as previously discussed, is non-toxic to fish in small concentrations and is used by plants and algae as fertilizer. Completing the cycle, the fish eat the plants and again excrete ammonia. Since nitrite is an intermediate form or step in the nitrogen cycle, typical measurements are in the range of 0.1 to 0.2 mg/L or below detection.

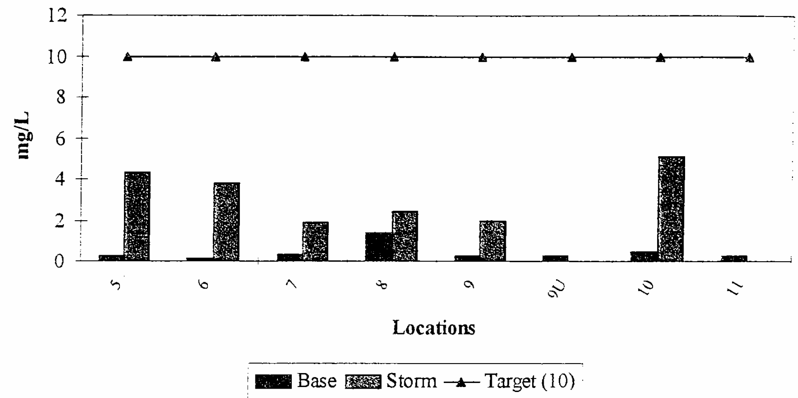
Too few nitrates in solution results in an inadequate nutrient supply for aquatic organisms, which also results in lower diversity and reduced quality of aquatic life. Less decay results in less ammonia, which can lead to a breakdown in the nitrogen cycle. The surface water quality target

Figure V-15
Brush Creek Reservoir
Nitrate-Nitrite Concentrations



set by the State is a maximum of 10 mg/L.

Figure V-16
Brush Creek Stream
Nitrate-Nitrite Concentrations



H. Ammonia Nitrogen

Ammonia toxicity to fish is linked to water temperature and pH. Surface water quality limits are under consideration to define criteria maximum concentrations (CMC or acute criterion) and criteria continuous concentrations (CCC or chronic criterion). In addition, there are differences in species acute sensitivity such that different CMC values were derived for waters where salmonids (trout, salmon) are present and where salmonids are not present, as salmonids tend to be more sensitive to ammonia.

The trend is that CMC level targets decrease as pH increases; however, CMC level targets increase slightly as temperature increases. Figure V-21 shows the results of ammonia monitoring in tributaries of Brush Creek. Samples collected from Brush Creek itself were below detection levels when tested for ammonia. The graph sets CMC targets relative to pH. All samples collected had ammonia levels below the CMC set at 3.20 mg/L. Ammonia is a measure of the reduced form of nitrogen and is a basic building block for proteins. Ammonia is the form of nitrogen produced by nitrogen-fixing bacteria and is the form in which nitrogen commonly appears in polluted streams. It is directly useable by living organisms, and constitutes an essential macronutrient in aquatic ecosystems.

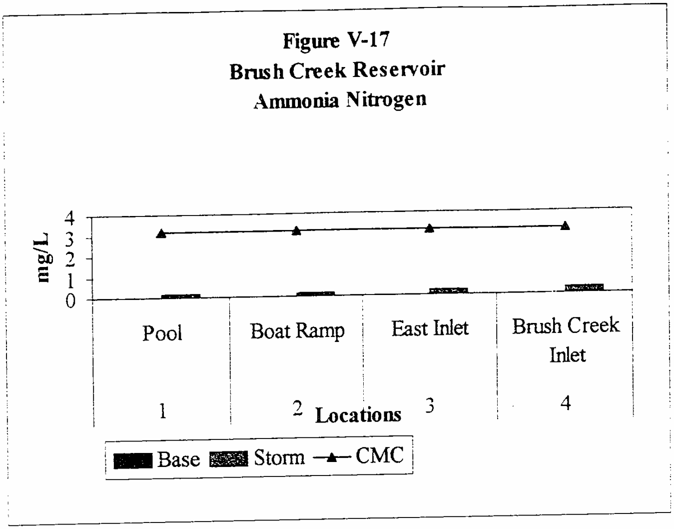


Figure V-17
Brush Creek Reservoir
Ammonia Nitrogen
mg/L
4
3
2
1
0
Pool
Boat Ramp
East Inlet
Brush Creek Inlet
1
2
3
4
Locations
Base
Storm
CMC

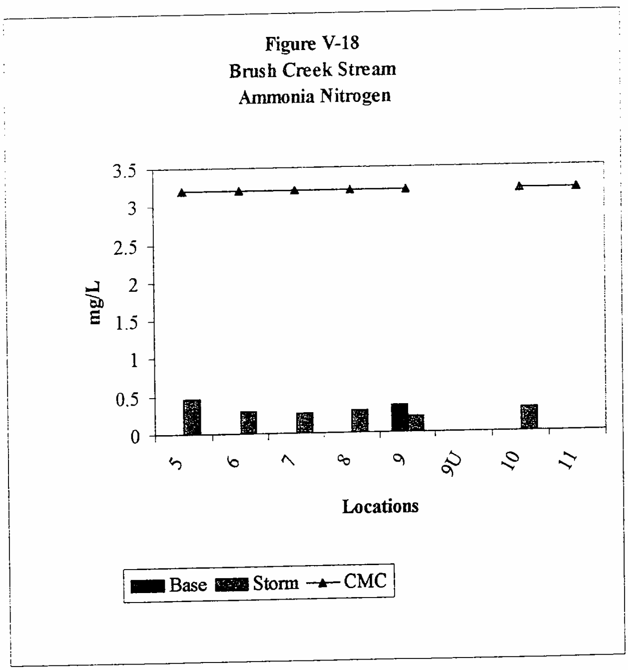


Figure V-18
Brush Creek Stream
Ammonia Nitrogen
mg/L
3.5
3
2.5
2
1.5
1
0.5
0
5
6
7
8
9
9U
10
11
Locations
Base
Storm
CMC

I. Total Kjeldahl Nitrogen

There are several laboratory tests used to measure the different forms of nitrogen. In order to determine organic and ammonia nitrogen, the test commonly used is Total Kjeldahl Nitrogen (TKN). Since TKN measures both ammonia nitrogen and organic nitrogen, it is standard procedure to also measure the ammonia nitrogen as discussed above. This in turn can be used to determine the fraction of the TKN that is associated with the organic nitrogen.

Typical levels in natural waters range from 0.2 to 2.0 mg/L therefore the target was set at 2.0 mg/L for TKN. TKN levels in base flow samples collected from Brush Creek Reservoir and the streams were all below the target. Samples collected following the precipitation event were generally higher and nearly all stream samples were above the target set at 2.0 mg/L.

Figure V-19
Brush Creek Reservoir
TKN Concentrations

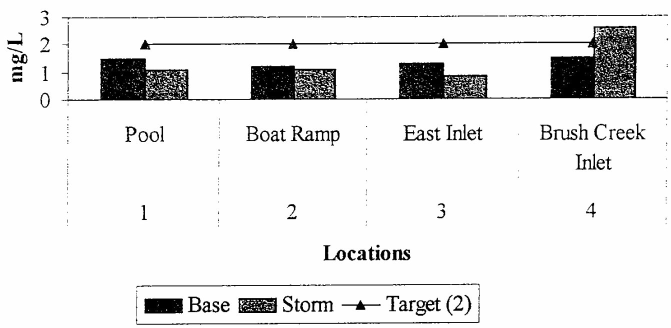
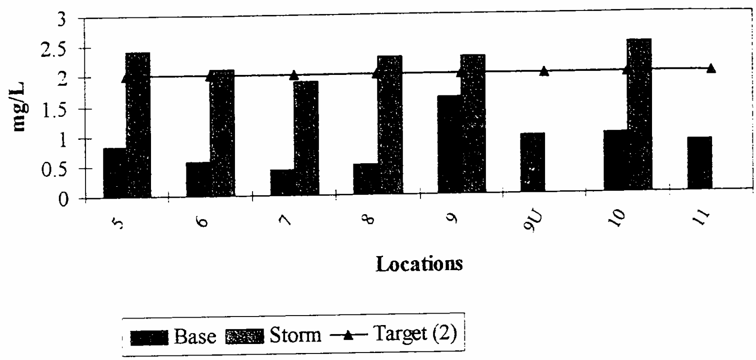


Figure V-20
Brush Creek Stream
TKN Concentrations



J. Total Nitrogen

The total Nitrogen of a sample is assumed to be the TKN concentration plus the nitrate nitrogen measurement.

Figure V-21
Brush Creek Reservoir
Total Nitrogen Concentrations

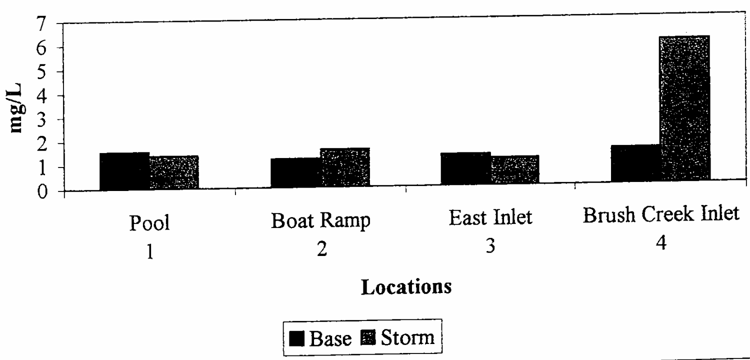
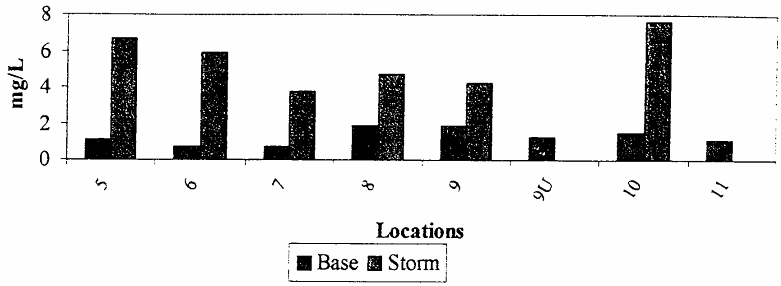


Figure V-22
Brush Creek Streams
Total Nitrogen Concentrations

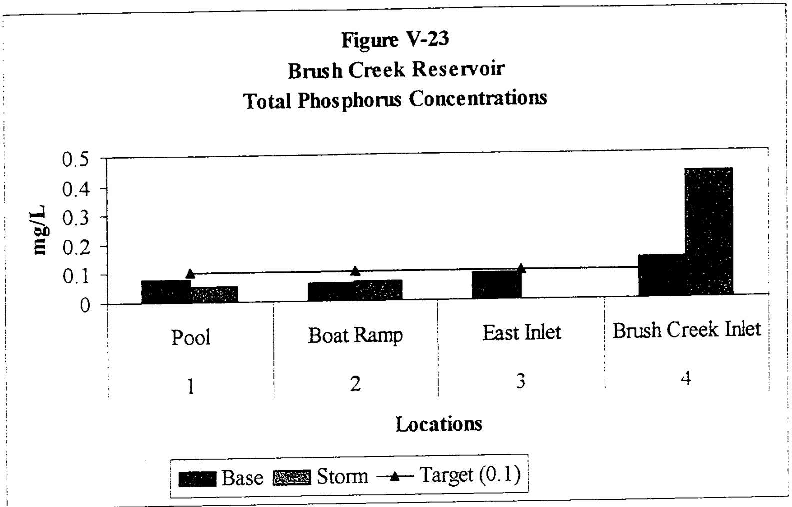


K. Phosphorus

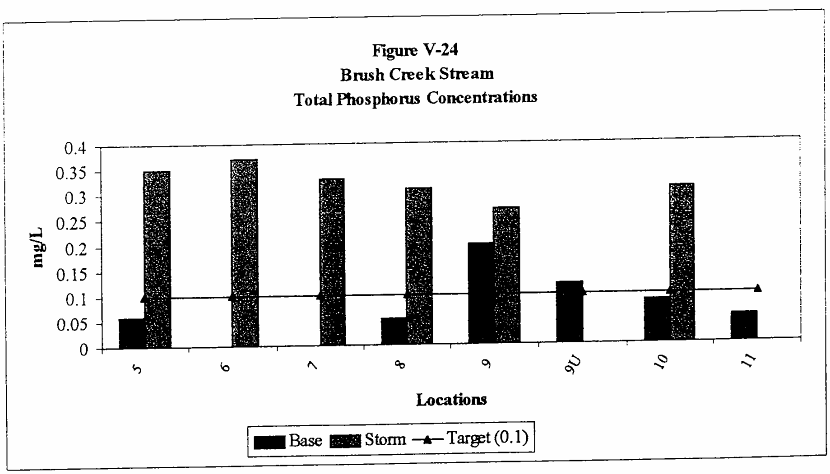
Phosphorus is the most important factor in the cultural eutrophication of streams throughout the world. Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in shortest supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable evens in a stream, including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic, the form required by plants. Animals can utilize either organic or inorganic phosphate. Both organic and inorganic phosphate can either be dissolved in the stream water or suspended in the water column.

There are a large number of sources and a variety of routes that phosphorus can take making it difficult to monitor or correct problems with phosphorus over-enrichment. Two basic references for phosphorus analysis methods include a total of twelve different tests for phosphorus. Total phosphorus is the form of greatest interest since total phosphorus includes potentially available as well as immediately available phosphorus. Carlson's Trophic State Index for lakes categorizes lakes with the poorest water quality as being hypereutrophic and that system uses total phosphorus as an indicator. Hypereutrophic lakes generally have a total phosphorus concentration of >0.1 mg/L (100 ppb) which is the value set as the target for the Brush Creek watershed monitoring. Base flow samples collected at the main inlet to the reservoir and at sample location 9, where cattle have free access to the stream, exceeded the target. Essentially all



sample locations within Brush Creek and all sampled tributaries had phosphorus levels exceeding this target following the storm event, including the main inlet to the reservoir.



L. Dissolved Phosphorus

Dissolved phosphorus is that portion that is readily available to algae and plants. It does not include inorganic condensed phosphate forms, such as those found in detergents.

Aquatic plants require nitrogen and phosphorus in different amounts. Typically the range of nitrogen to phosphorus required is from 5 to 20 (N:P 5-20) such that phosphorus is the limiting nutrient. When the ratio deviates from this range, plants cannot use the nutrient present in excess amounts. The other nutrient, in this case phosphorus, is then considered to be the limiting nutrient on plant growth. In streams experiencing excessive nutrient loading, the typical approach is to control loading of the limiting nutrient at levels that prevent nuisance conditions.

Laboratory analysis for Dissolved Phosphorus was quantified to the 0.05 mg/L concentration level even though concentrations below that level may be sufficient to allow nuisance conditions to develop. Since concentrations below 0.05 mg/L were not quantified, the target for this project is set at 0.05 mg/L and this target was exceeded at all Brush Creek stream sampling locations and at the main inlet to Brush Creek Reservoir.

Figure V-25
Brush Creek Reservoir
Dissolved Phosphorus Concentrations

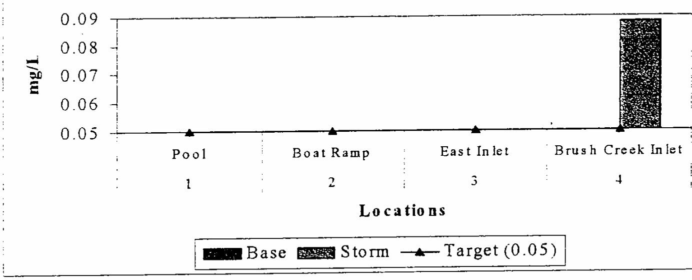
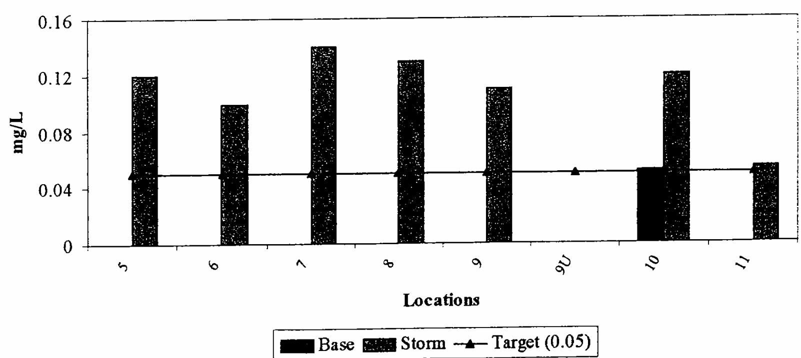


Figure V-26
Brush Creek Stream
Dissolved Phosphorus Concentrations



3. Total N & Total P Loading

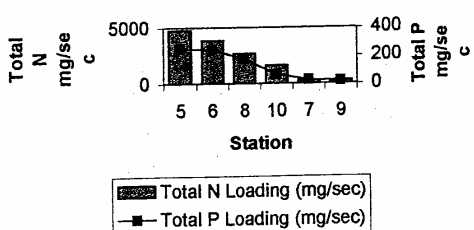
Previous sections have presented the results of water quality testing as *concentrations* based on the mass of a particular parameter contained in a unit of water- most often as milligrams per liter. A meaningful alternative represents the parameter as the mass being carried in the stream or being delivered to the lake per unit of time, referred to as *mass loading*. The high concentration of a contaminant may suggest significant impacting to the reservoir, however, if flow is minimal, mass loading may result in little or no impact. Conversely, if relatively low concentrations are measured, impact to the water body may still be significant if coupled with significant flow. Table presents mass loading predictions for Total N and Total P. These calculations represent mass loading of nitrogen and phosphorus following the significant precipitation event. Stations 5, 6, 8, & 10 represent locations along Brush Creek with 10 being the most upgradient.

As sampling stations along Brush Creek proceed upstream, the contributing watershed acreage decreases and, as one expects, mass loading decreases. Stations 7 and 9 show a similar pattern as they represent down gradient and upgradient locations, respectively, on an unnamed tributary of Brush Creek.

Table V-4 Total N & Total P Loading

Station	Flow (cfs)	Total N Conc. (mg/L)	Total P Conc. (mg/L)	Total N Loading (mg/sec)	Total P Loading (mg/sec)
5	25	6.7	0.35	4743	248
6	23	5.9	0.37	3842	241
8	20	4.7	0.31	2662	176
10	7.5	7.6	0.31	1614	66
7	2.7	3.8	0.33	291	25
9	2.5	4.242	0.27	300	19

Figure V - 27
Total N & Total P Mass Loading



4. Fecal Coliform

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. They aid in the digestion of food. A specific subgroup of this collection is the fecal coliform bacteria, the most common member being Eschericia coli. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals. Bacteria reproduce rapidly if conditions are right for growth. Most bacteria grow best in dark, warm, moist environments with food.

The presence of fecal coliform bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. Fecal coliform bacteria can enter streams or a reservoir through direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated human sewage. Individual home septic tanks can become overloaded during the rainy season and allow untreated human wastes to flow into drainage ditches and nearby waters. Agricultural practices such as allowing animal wastes to wash into nearby streams during the rainy season, spreading manure and fertilizer on fields during rainy periods, and allowing livestock watering in streams can all contribute fecal coliform contamination.

At the time this occurs, the source water may be contaminated by pathogens or disease producing bacteria or viruses, which can also exist in fecal material. Some waterborne pathogenic diseases include ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A. The presence of fecal coliform tends to affect humans more than it does aquatic creatures, though not exclusively. While these bacteria do not directly cause disease, high quantities of fecal coliform bacteria suggest the presence of disease causing agents. The presence of fecal contamination is an indicator that a potential health risk exists for individuals exposed to this water.

Untreated fecal material, such as contains fecal coliform, adds excess organic material to the water. The decay of this material depletes the water of oxygen. This lowered oxygen may kill fish and other aquatic life. Reduction of fecal coliform in wastewater may require use of chlorine and other disinfectant chemicals. Such materials may kill the fecal coliform and disease bacteria. They also kill bacteria essential to the proper balance of the aquatic environment, endangering the survival of species dependent on those bacteria. So, higher levels of fecal coliform require higher levels of chlorine, threatening those aquatic organisms.

The new USEPA coliform rule requires major monitoring changes by the drinking water industry. The testing requirements for drinking water are markedly increased. Not only is the number of routine coliform tests increased, especially for the smaller utilities, but also a new regulation requires automatic repeat testing from all sites that show a total coliform positive.

The current USEPA recommendations for body-contact recreation is fewer than 200 colonies/100 mL; for fishing and boating, fewer than 1000 colonies/100 mL; and for domestic water supply, for treatment, fewer than 2000 colonies/100 mL. The drinking water standard is less than 1 colony/

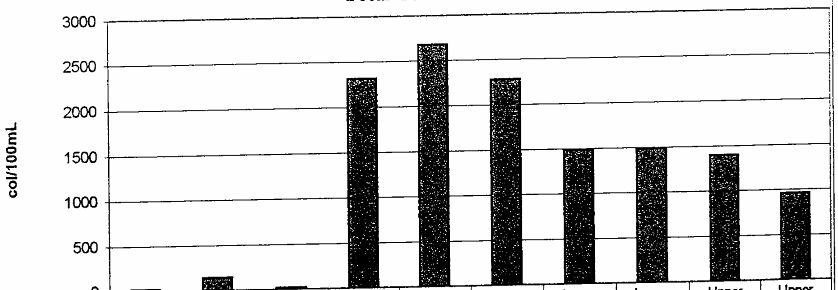
100ml. The State of Indiana standard for body-contact recreation specific to E. coli, a strain of fecal coliform. That target has been set at 235 colonies/100mL

Samples for fecal coliform were collected following a rain event on June 6, 2001. Four samples were collected from the reservoir and six from Brush Creek or its tributaries.

Unlike the other conventional water quality parameters, fecal coliform bacteria are living organisms. They multiply quickly when conditions are favorable for growth and die in large numbers when they are not. Because bacterial concentrations are dependent upon specific conditions for growth and these conditions change quickly, fecal coliform bacteria counts are not easy to predict. For example, although winter rains may wash more fecal matter from urban areas into a lake, cool water temperatures may cause many of the organisms to die. Direct exposure to sunlight (with its ultraviolet disinfection properties) is also lethal to bacteria, so die-off may be high even in the warmer water of summertime.

The test results for fecal coliform are summarized and graphed below. Water temperatures ranged from 19 to 23 degrees C when samples were collected which would be conducive to bacterial growth. The lower levels in the reservoir are assumed to be resultant of the bacteria exposure to ultraviolet rays of sunlight. All fecal coliform levels detected in Brush Creek and tributaries exceed the body-contact recreation standard.

Figure V-28
Brush Creek
Fecal Coliform



Location	Pool 1	Boat Ramp 2	East Inlet 3	Brush Creek Inlet 4	Lower Watershed 5	Mid Watershed 6	Lower South Fork 7	Lower North Fork 8	Upper South Fork 9	Upper North Fork 10
col/100mL	20	140	20	2320	2680	2280	1480	1480	1400	960

VI. RESERVOIR ANALYSIS

Lakes are complex ecosystems in which physical, chemical, and biological characteristics function interdependently. Large-scale factors, such as climate and geology, set the stage within which individual lake characteristics develop. Lakes in northern Indiana tend to be highly productive, hardwater lakes surrounded by forested wetlands. These lakes age naturally over hundreds of years. Some physical and chemical factors, like temperature and light, determine the type of organisms that can survive in the system. Other physical and chemical factors, like dissolved oxygen, may result from biological activity. Physical, chemical, and biological characteristics of Brush Creek Reservoir are described below.

1. Methods

The water sampling and analytical methods used for Brush Creek Reservoir were consistent with the requirements of the IDNR Lake and River Enhancement Program for purposes of calculating the IDEM Eutrophication Index and Carlson's Trophic State Index. Parameters included:

- Secchi Depth
- Light Penetration
- Plankton
- Chlorophyll-a
- pH
- Conductivity
- Temperature
- Dissolved Oxygen
- Ammonia N
- Total Kjeldahl Nitrogen (TKN)
- Nitrite N
- Organic N
- Total N
- Total Phosphorus
- Dissolved Phosphate
- Turbidity

Water samples were collected for the various parameters on August 8, 2001 from the reservoir at the deepest part of the lake near the dam. Samples were collected from the near surface epilimnion and the bottom (hypolimnion) region. Temperature and dissolved oxygen measurements were collected at one meter intervals for profilings and plankton tows were performed.

2. Profiles

Brush Creek Reservoir exhibited thermal and chemical stratification during late summer sampling on August 8, 2001. With the exception of very shallow lakes, most lakes in Indiana will stratify so that warmer water remains near the surface of the lake and water at the bottom is colder. Due to the difference in temperature and density, warmer water from the surface "floats" on top and does not mix with denser, colder water at the bottom. As a result, chemical characteristics of surface and bottom water may differ dramatically, such that few organisms can live in deeper parts of the lake in summer. Field parameters were collected at four separate areas to generate the following profiles shown as Figure VI-1.

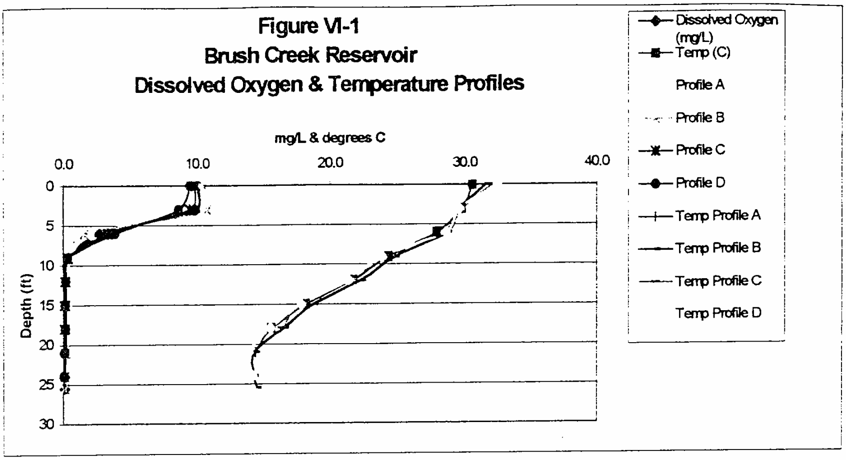
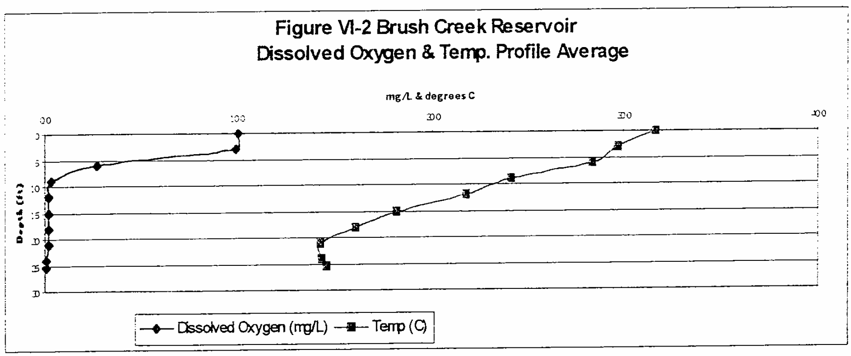


Figure VI-2 represents an average of the compiled data collected at the four locations.



A. Light Transmission/ Secchi Disk Depth

Water clarity is affected by algae, soil particles, and other materials suspended in the water. Secchi disk depth is primarily used as an indicator of algal abundance and general lake productivity. Although it is only an indicator, Secchi disk depth is the simplest and one of the most effective tools for estimating a lake's productivity.

Secchi disk readings vary seasonally with changes in photosynthesis and, therefore, algal growth. In most lakes, Secchi disk readings begin to decrease in the spring, with warmer temperature and increased growth, and continue decreasing until algal growth peaks in the summer. As cooler weather sets in and growth decreases, Secchi disk readings increase again. (However, cooler weather often means more wind). In a shallow lake, the improved clarity from decreased algal growth may be partly offset by an increase in concentration of sediments mixed into the water column by wind. In lakes that thermally stratify, Secchi disk readings may decrease again with fall turnover. As the surface water cools, the thermal stratification created in summer weakens and the lake mixes. The nutrients thus released from the bottom layer of water may cause a fall algae bloom and the resultant decrease in Secchi disk reading.

Rainstorms also may affect readings. Erosion from rainfall, runoff, and high stream velocities may result in higher concentrations of suspended particles in inflowing streams and therefore decreases in Secchi disk readings. On the other hand, temperature and the volume of the incoming water may be sufficient to dilute the lake with cooler, clearer water and reduce algal growth rates. Both clearer water and lower growth rates would result in increased Secchi disk readings.

The natural color of the water also affects the readings. In most lakes, the impact of color may be insignificant. But some lakes are highly colored. Lakes strongly influenced by bogs, for example, are often a very dark brown and have low Secchi readings even though they may have few algae.

There is a direct correlation between Secchi disk depth and light transmission depth. The rule of thumb is that light can penetrate to a depth of from 1.7 to 3 times the Secchi disk depth. For calculating the 1% light transmission depth in this study, a multiplier of 2.7 was used. Secchi disk depth readings measured from 2.0 ft to 2.4 ft at four pool locations on Brush Creek Reservoir with the average being 2.1 ft. The 1% light level was calculated then to be 5.7 feet.

B. Plankton Tows

Plankton tows were collected from a depth of from 5 feet to the surface and from 10 to 5 feet from the surface with the later tow representing the thermocline. Five feet by five-inch tows were collected in 120 ml jars using a Wildco Plankton Net. Samples were preserved and sent to the Water Research Lab at Northern Kentucky University in Highland Heights, Kentucky.

The New South Wales (NSW) Blue-Green Algae Task Force has established algal alert levels to minimize the impacts of toxic cyanobacteria for general water supplies (Yoo et al. 1995). The NSW Task Force has established three alert levels:

Level	Units/ml	Alert framework
1	500-2,000	Identify the type of algae
2	2,000-15,000	Confirm type-Look for metabolites
3	Above 15,000	Implement appropriate treatment

The Water Research Lab uses the low end of Alert Level 2 (2000 algal units/mL) as an alarm level. However, neither of the samples even reached alarm level I. Both of the Brush Creek samples were dominated by blue-green algae. The 0-5 sample consisted of about 44% blue-green algae and the 5-1 0 sample was consisted of about 46%. Blue-green algae are often taste and odor indicators for drinking water facilities as well as toxin producers. Thirty-two percent of each sample was *Aphanizomenon,* a filamentous bluegreen algae that is capable of producing toxins and taste and odor episodes. The chlorophyll readings are not consistent with a typical stratified lake. It is uncharacteristic for the hypolimnion at 4 μg/L to have a higher concentration of chlorophyll than the epilimnion at 0 µg/L. However, chlorophyll values below 5 µg/L are considered insignificant. Also, incorrect filters were used to filter the water for the chlorophyll analyses that may have affected the results.

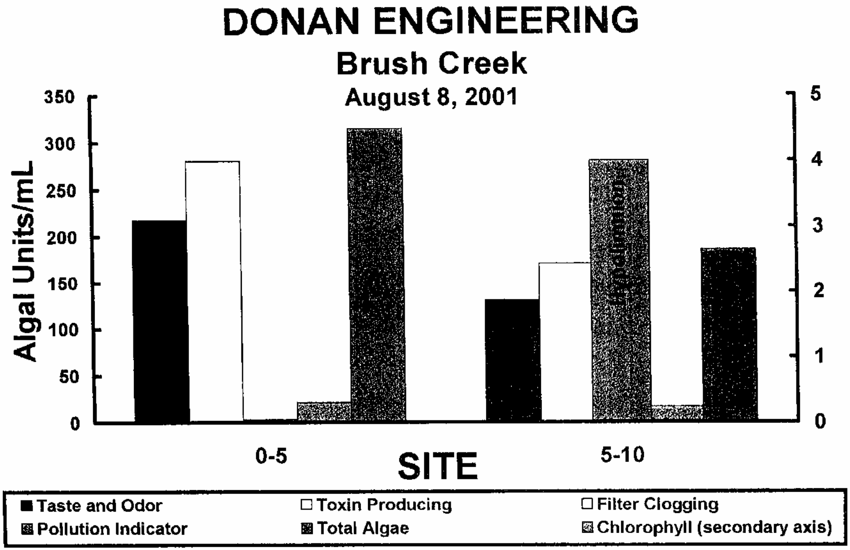
Of the zooplankton, both of the Brush Creek samples were dominated by rotifers. A dominance of rotifers indicates a high density of small planktivorous fish or a low density of larger carnivorous fish. According to food chain dynamics, a high density of small planktivorous fish will reduce the density of the larger zooplankton, such as copepods or cladocera that feed on smaller zooplankton such as rotifers. Furthermore, there may be few large fish to reduce the population of the smaller planktivorious fish. Also, rotifers are inefficient filter feeders. They are unable to feed on larger algae such the filamentous *Aphanizomenon* that dominates the Brush Creek Reservoir samples. The full reports of the plankton and chlorophyll analysis are included in the Appendix.

Table VI-1

Brush Creek Plankton Summary

								Calculated using Concentration Factor	
					Site:	0-5	5-10	0-5	5-10
					Date:	08/08/01	08/08/01	08/08/01	08/08/01
Genus	Type	Indicator				#/mL	#/mL	#/mL	#/mL
Anabaena	Blue-Green Algae	T	X	F	P	0	1,457	0.000	5.246
Aphanizomenon	Blue-Green Algae	T	X			40,880	33,382	196.222	120.174
Centric Diatom	Diatom					2,291	265	10.995	0.954
Chlamydomonas	Green	T			P	0	132	0.000	0.477
Cocconeis	Diatom					0	132	0.000	0.477
Cosmarium	Green	T				176	132	0.846	0.477
Cymbella	Diatom			F		176	0	0.846	0.000
Euglenoid	Euglenoid	T			P	0	397	0.000	1.431
Mallomonas	Chrysophyte					0	265	0.000	0.954
Merismopedia	Blue-Green Algae		X			5,462	1,325	26.219	4.769
Nitzschia	Diatom			F	P	352	1,722	1.692	6.199
Pandorina	Green	T			P	3,877	795	18.607	2.861
Scenedesmus	Green	T			P	176	132	0.846	0.477
Spirulina	Blue-Green Algae		X			11,982	11,260	57.513	40.535
Synedra	Diatom	T		F		176	0	0.846	0.000
Asplancha	Rotifer					3	2	0.013	0.006
Brachionus	Rotifer					23	2	0.109	0.007
Calanoid	Copepod					0	1	0.002	0.002
Cyclopoid	Copepod					0	1	0.001	0.004
Filinia	Rotifer					3	1	0.013	0.003
Nauplius larvae	Copepod					3	3	0.016	0.010
Polyartha	Rotifer					17	4	0.081	0.013
Trichocerca	Rotifer					3	5	0.016	0.017
						65,601	51,415	315	185
Taste and Odor Algae (Units/mL):						45.285	36.428	217.367	131.142
Toxin Producers (Units/mL):						58.324	47.423	279.955	170.723
Filter Cloggers (Units/mL):						705	3.179	3.383	11.445
Pollution Indicators (Units/mL):						4.405	4.636	21.145	16.691
Blue-green Algae (Units/mL):						58.324	47.423	279.955	170.723
Indicator Definitions:	Chrysophyte (Units/mL):					0	265	0.000	0.954
F=Algae that are know to clog filters	Diatom (Units/mL):					2.995	2.119	14.378	7.630
P=Algae that are found in polluted water	Euglenoid (Units/mL):					0	397	0.000	1.431
T=Algae that are capable of producing tastes and odors	Green Algae (Units/mL):					4,229	1,192	20.299	4.292
X=Algae that are capable of producing toxins									
	Cladoceran (Units/mL):					0	0	0.002	0.000
	Copepod (Units/mL):					4	5	0.019	0.017
	Rotifer (Units/mL):					48	13	0.232	0.047
Concentration Factor	=volume collected/volume filtered					EPI	HYPO	EPI	HYPO
Chlorophyll (ug/L):						0	4	0.000	4.000

Figure VI-3 Plankton Concentration



C. Nutrient Levels

Nutrients in lakes serve the same basic functions as nutrients in soil- productivity. They are essential for plant growth in soil where productivity is considered beneficial, but this is not necessarily so in a lake. The additional algae and other plant growth allowed by the nutrients may be beneficial up to a point, but soon becomes a nuisance.

The main nutrients of concern are phosphorus and nitrogen. Both elements are measured in several forms. Phosphorus can be measured as total phosphorus or as soluble reactive phosphate (SRP) or dissolved phosphorus. SRP represents the fraction of TP that is available to organisms for growth. Nitrogen can be measured as total nitrogen (TN), total Kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3), nitrite-nitrogen (NO_2) [these are usually measured as nitrate-nitrite-nitrogen ($NO_3 - NO_2$), or ammonia-nitrogen (NH_4). TN is similar to TP and is used to represent the total amount of nitrogen in a sample.

One chemical form of an element can be converted into another. The conditions under which the conversion occurs are influenced by many factors, such as pH, temperature, oxygen concentration, and biological activity. The total concentration of a nutrient (e.g., TP or TN) is not necessarily the most useful measurement. For example, if a sample is analyzed for TP, all forms of the element are measured, including the phosphorus "locked up" in biological tissue and insoluble mineral particles. It may be more useful to know the concentration of phosphorus that is actually available for growth. Dissolved phosphorus better reflects bioavailability.

Although there are many different forms of nutrients that can't be measured, there are only three commonly used combinations. These are (1) measure all forms of both elements – TP, SRP, TN, NO_3- NO_2, NH_4; (2) measure only total nutrients – TP and TN; or (3) measure only available nutrients – SRP, NO_3- NO_2, and NH_4. (In the first example, TKN could be measured instead of TN. Depending upon which form is measured, the other can be estimated by difference.)

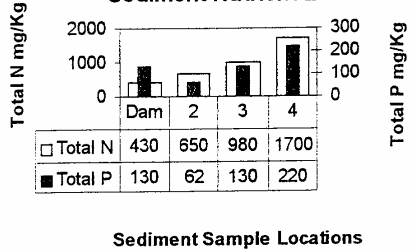
Results of epilimnion and hypolimnion physical and chemical analysis are summarized in the following table.

Table VI-2. Lake Pool Water Quality Characteristics

Parameter	Epilimnion Sample (1-3 ft)	Hypolimnion Sample (18 ft
Secchi Depth	2.1	-
1% Light Level (calculated)	5.7	-
pH	8.67	7.75
Conductivity	247 µmhos	394 µmhos
Temperature (°C)	31.7	16.1
% Dissolved Oxygen	138	1.1
Dissolved Oxygen	10.1 mg/L	0.1
Nitrogen, Ammonia	<0.10 mg/L	3.9 mg/L
Nitrogen, Kjeldahl	1.5 mg/L	4.9 mg/L
Nitrogen, Nitrate-Nitrite	0.026 mg/L	0.020 mg/L
Nitrogen, Organic	1.5 mg/L	1.0 mg/L
Nitrogen, Total	1.526 mg/L	4.920 mg/L
Phosphorus, Total	0.080 mg/L	0.40 mg/L
Phosphorus, Dissolved	<0.05 mg/L	0.13 mg/L
Turbidity	7.8 NTU	20 NTU
Chlorophyll-a	0.0 ug/L	4.0 ug/L

3. Sediment

Figure VI-4 Brush Creek Reservoir Sediment Nutrient Levels



Sediment samples were collected from the bottom of the reservoir at four different locations: one at the lake pool station near the dam and one at each of the three sampled inlets. Samples are identified by the same numbers used to identify the sampled inlets. Samples were collected using an Eckman sediment dredge and all samples were laboratory tested for total phosphorus, ammonia, nitrate-nitrite nitrogen, TKN, and total nitrogen. Sediment nutrient levels are presented in Figure VI-4.

The total N levels at Brush Creek Reservoir ranged from 430 mg/Kg of sediment at the dam to 1,700 mg/Kg in the sample taken at the mouth of the reservoir. Total phosphorus ranged from 62 mg/Kg at the inlet by the boat ramp to 220 mg/Kg at the main inlet. The Indiana

Dept. of Environmental Management reported on average maximum background nutrient levels in lake sediments in their Indiana 305 (b) report of 1986-1987. The report states that maximum background concentrations of nitrogen (reported as TKN) were found to be 1,500 mg/Kg. The report further states that sediments containing less than two times the maximum background concentration were classified as "uncontaminated". Therefore, samples with less than 3,000 mg/Kg TKN area classified as uncontaminated. Using this guideline, samples collected from Brush Creek Reservoir are below the maximum background except for the sample collected at the main inlet. While that sample is classified as uncontaminated, it clearly serves as more of a nutrient source of nitrogen from sediment represented by the sample collected near the dam.

The total phosphorus at Brush Creek Reservoir ranged from 62 mg/Kg to 220 mg/Kg at the main inlet. The Indiana 305 (b) report indicates maximum background levels for total P averaged 610 mg/Kg. Following the same rationale, sediments containing less than two times the maximum background concentration were classified as "uncontaminated". Therefore, all sediment samples had total P levels less than the maximum background level. The sample taken at the main inlet however, clearly had a significantly higher level than other samples collected from the reservoir.

4. Morphometry

Brush Creek Reservoir was constructed in 1952 with a design pool volume of some 2,000-acre feet. Donan relied on a drawing entitled Brush Creek Dam and Reservoir Site, March 1952 prepared by or for the Indiana Flood Control and Water Resources Commission to prepare depth-area and depth-volume curves for the reservoir. Also available was a bathymetric map prepared by the Division of Water and dated December of 1989. The contours of both drawings were used to generate depth-area and depth-volume curves.

Table VI-3 Depth-Volume Curve Brush Creek Reservoir

	1989		1952	
Depth (Ft)	Area (Acres)	Acre-Feet	Area (Acres)	Acre-Feet
0	149.44	0	187.34	0
5	123.14	681	138.59	815
10	84.00	1199	105.83	1426
15	44.73	1521	48.76	1812
20	21.44	1687	24.25	1995
25	4.24	1751	3.62	2065
30	0.12	1762	0.11	2074

These contour maps indicate that the design volume, according to the planimetered areas of each contour, was 2,074 acre-feet. By the same method, the 1989 volume was measured to be 1,762 acre-feet. This change represents a reduction of greater than 15%. Due to lack of information concerning the methods employed to generate the contours of these maps, their accuracy may be questionable and it is not conclusive that the volume of the reservoir has been reduced by 15%.

These curves are useful for determining the extent of shallow habitat where rooted plants could grow and recognizing the trend toward a smaller surface area. The curves also show the volume of water below the mixing zone and the trend for the reduction of that volume. As an example, the volume of water below 10 feet from the surface when the structure was built was 648 acre-feet (2,074 ac-ft - 1,426 ac-ft). This accounted for 31.2% (648 ac-ft./2,074 ac-ft) of the reservoir volume. In 1989, the volume below 10 feet was 563 ac-ft (1,762 ac-ft. - 1,199 ac-ft), which still was 32% (563 ac-ft./1,762 ac-ft.) of the total volume. However, the volume of deep water was reduced by 85 ac-ft. The same calculations applied to the top 10 feet of the reservoir show that the volume nearest the surface was reduced by 227 ac-ft., which is a 16% reduction.

Figure VI-5 Depth Volume Curve Brush Creek Reservoir

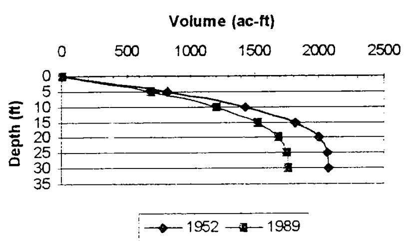
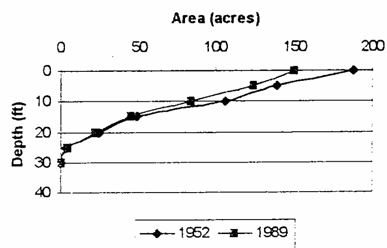


Figure VI-6 Depth-Area Curve Brush Creek Reservoir



It is beyond the scope of this study to generate updated contours for a new bathymetric map of Brush Creek Reservoir. However, soundings were performed in an effort to represent changes due to sedimentation at major inlets. A weighted Secchi disk attached to a graduated line was used to measure depths at cross sections of three inlets to the reservoir as shown in Figure VI-7. Cross sections or transects across inlets were measured or approximated using a Hip Chain distance measuring unit. These measurements were used to produce the 2001 cross sections versus the 1989 cross sections taken from the contours of the available map from the Division of Water. Although both sources of cross sectional information are regarded as approximations, the comparison suggests significant sediment deposition in the inlet areas since 1989.

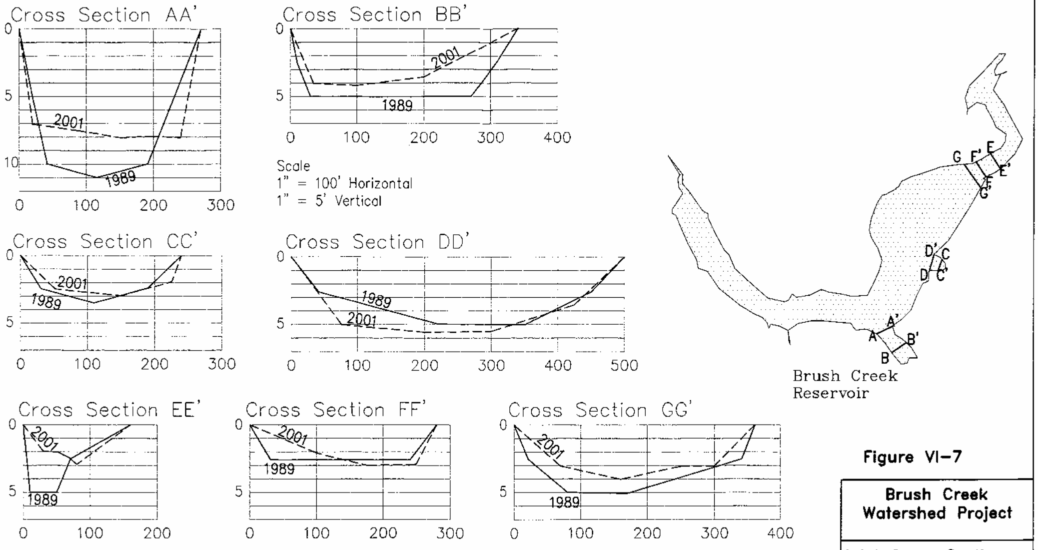


Figure VI–7

Brush Creek Watershed Project

Inlet Cross Section Map

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5. Aquatic Vegetation

Aquatic plants are an integral part of a lake's ecosystem. Therefore, their indiscriminate removal can severely disrupt the natural balance in the system. That balance is directly affected by the way that land adjacent to the lake is used or managed. Poor management of the land can negatively affect a lake, resulting in lower property values, impaired fishing quality, and reduced aesthetic appearance. Mismanagement of the aquatic and shoreline plants will disrupt fish and wildlife habitat, possibly leading to impacts as dramatic as fish kills.

Aquatic plant species are adapted for growth in particular parts of a lake, wetland, or other water body, depending on its physical characteristics. Limnologists categorize different habitat types by water depth (littoral and pelagic zones) and by the extent to which sunlight can penetrate the water (photic and aphotic zones). The abundance and distribution of algae and macrophytes in a lake depend on light availability, water clarity, water depth, nutrient availability, type of substrate (bottom material), and degree of disturbance. Human activities in and around the lake and its natural physical characteristics (e.g., shape and size) influence these factors.

Light availability is the single most important factor regulating plant growth. Most underwater plants cannot survive with less than 1%of the sunlight that enters the water 's surface. Seasonal patterns of light (and temperature) cause different plant species to grow at different times of the year.

Water clarity (or degree of turbidity) determines how much sunlight can penetrate the water. Dissolved substances and suspended matter in the water column affect clarity. For instance, an increase in phytoplankton or soil particles eroded from the watershed or shoreline will block sunlight, reducing its availability to submerged macrophytes. Some fish species, such as carp, stir bottom sediments when feeding. An overabundance of carp can cause cloudy water and disrupt growth of rooted aquatic plants. Without rooted plants and light, fish and wildlife diversity can disappear from the lake.

Water depth (along with shore land and underwater slope, surface area, and shape) affects a lake's chemical and biological attributes by determining the size of the shallow water, or littoral zone. Overall, shallower lakes are more productive with respect to algae and macrophyte growth. Deep lakes with steep sides and few bays tend to have fewer aquatic plants.

Nutrients are required for aquatic plant growth. Although nitrogen stimulates growth of both land and aquatic plants, it is the addition of phosphorus that usually stimulates excessive growth of aquatic plants. These nutrients occur naturally in lakes as a result of biological and physical processes. However, their presence in excessive amounts is usually due to human activities in a watershed. Cropland tillage, livestock production, lawn and field fertilization, septic system use, and shoreline vegetation removal all can increase the amount of nutrients entering a lake.

Since phosphorus binds to soil particles and nitrogen dissolves in water, both can be transported by runoff from surrounding land. Once in the lake, they may be recycled by plant decay or the mixing of deep and surface waters. Excessive levels of nutrients result in excessive plant growth and increased eutrophication, both of which can impair the lake 's desired uses.

Substrate (or type of bottom material) greatly influences growth or productivity of aquatic plants and animals. Plants root more readily and spread faster in soft soils. In addition, the substrate 's chemical and physical composition affects the amount of nutrients available, influencing both plant distribution and growth rate. For instance, marl areas support few aquatic plants, rocky lakebeds will likely have fewer plants than ones with silt substrates, and eroded soil can contribute to the increased spread or density of nuisance aquatic plants. Sandy lakebeds mixed with some organic matter usually support the greatest diversity of native aquatic species.

Water movement (or current) can also influence plant growth and distribution. Macrophytes need to be rooted in the soil to obtain nutrients and maintain a position at specific light and depth levels. Waves, strong currents, and power boating can tear plants from the lakebed. However, loss of rooted plants and water mixing caused by currents, waves or high-speed boating may promote phytoplankton growth by enabling floating algae to stay suspended in the water column and use available sunlight and nutrients.

An aquatic vegetation reconnaissance survey was perfomed on Brush Creek Reservoir on July 30, 2002. The Secchi depth average on that day of 1.6 feet was used to estimate the littoral zone maximum depth of 4.8 feet. A total of seventeen locations were examined to document the presence and extent of submerged and emergent vegetation.

The majority of the shoreline has very steep (1:1 or steeper) side slopes resulting in an unusually narrow littoral band at the perimeter of the reservoir. In the lower two-thirds of the reservoir, the shoreline substrate is rock- mainly limestone and sandstone. The upper third has somewhat flatter sideslopes as the reservoir widens and the substrate turns to silt/clay soil material. At the upper end of the reservoir, deposited sediment serves as the substrate.

The only macrophytes observed were water willow (*Justicia americana*) and cattail (*Typha* spp.). Rake tosses at the sampling locations did not yield any submersed species. Water willow was found at the shoreline essentially around the entire perimeter of the reservoir while cattail was found in distinct beds that had silt/clay substrate. Table VI-4 summarizes the reconnaissance survey.

Table VI-4 Aquatic Vegetation Reconnaissance Survey Summary

Vegetation Survey Location	Substrate	Vegetation	Type	Abundance	Canopy
1	Silt/Clay	Water willow	Emergent	21-60%	>60%
2	Silt/Clay	Water willow Cattail	Emergent	>60%	>60%
3	Silt/Clay	Water willow	Emergent	>60%	>60%
4	Silt/Clay	Water willow & Cattail	Emergent	21-60%	21-60%
5	Silt/Clay	Water willow & Cattail	Emergent	21-60%	21-60%
6	Silt/Clay	Water willow	Emergent	>60%	>60%
7	Silt/Clay	Water willow & Cattail	Emergent	>60%	>60%
8	Silt/Clay	Water willow	Emergent	21-60%	2-20%
9	Silt/Clay	Water willow & Cattail	Emergent	21-60%	21-60%
10	Rock	Water willow	Emergent	2-20%	2-20%
11	Rock	Water willow	Emergent	2-20%	<2%
12	Rock	Water willow	Emergent	2-20%	<2%
13	Rock	Water willow	Emergent	2-20%	<2%
14	Rock	Water willow	Emergent	21-60%	2-20%
15	Rock	Water willow	Emergent	2-20%	2-20%
16	Rock	Water willow	Emergent	2-20%	<2%
17	Rock	Water willow	Emergent	2-20%	2-20%

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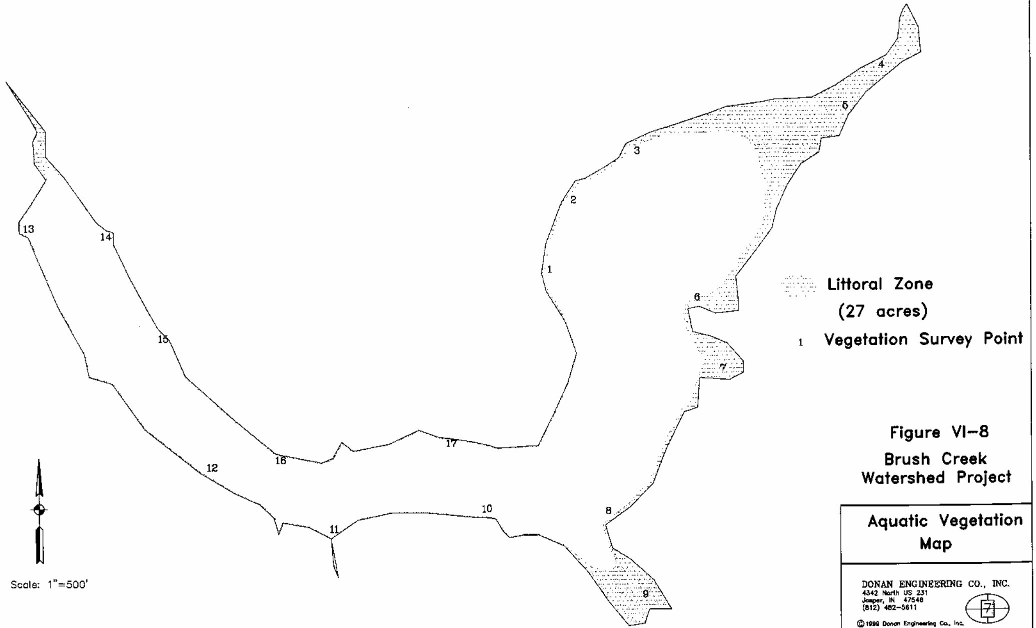

Figure VI-8
Brush Creek
Watershed Project

Aquatic Vegetation
Map

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PART VII. RESERVOIR & WATERSHED ASSESSMENT

1. Reservoir

Lakes created as reservoirs exhibit a different pattern of change from natural lakes in Northern Indiana. Reservoirs often have an initial period of very high water clarity and low productivity due to the low amount of organic material in the lake and high input from groundwater. Productivity increases over time from sedimentation and runoff in the watershed with the rate of increase dependent upon surrounding land use, topography, and soil types. Lack of more natural drainage patterns in artificial waterbodies can complicate lake development and management issues.

A. Eutrophication Index

The Indiana Trophic State Index, developed by IDEM, provides a convenient format for comparing and scoring various aspects of productivity and lake condition. This index ranges from 0 to 75 with the higher scores indicating more eutrophication, productivity, or lake aging. Eutrophication Index scores reflect the amount of nutrients, dissolved oxygen, water clarity, amount of phytoplankton, and relative abundance of blue-green algae in the water column. Unlike most terrestrial ecosystems, where nitrogen tends to be the limiting agent, productivity in most freshwater ecosystems are limited by the amount of available phosphorus. Both green and blue-green algae are dependent upon phosphorus present in water for growth. In contrast, several species of blue-green algae function similarly to legumes; they are capable of fixing nitrogen from the air and do not rely on ammonia or nitrate in the water.

TABLE VII-1
INDIANA TROPHIC STATE INDEX

Parameter and Range	Eutrophy Points	Brush Creek Score
I. Total Phosphorus (ppm)		
A. At least 0.03	1	
B. 0.04 to 0.05	2	
C. 0.06 to 0.19	3	
D. 0.2 to 0.99	4	4
II. Soluble Phosphorus (ppm)		
A. At least 0.03	1	
B. 0.04 to 0.05	2	
C. 0.06 to 0.19	3	3
D. 0.2 to 0.99	4	
E. 1.0 or more	5	
III. Organic Nitrogen (ppm)		
A. At least 0.5	1	
B. 0.6 to 0.8	2	
C. 0.9 to 1.9	3	3
D. 2.0 or more	4	
IV. Nitrate (ppm)		0
A. At least 0.3	1	
B. 0.4 to 0.8	2	
C. 0.9 to 1.9	3	
D. 2.0 or more	4	
V. Ammonia (ppm)		
A. At least 0.3	1	
B. 0.4 to 0.5	2	
C. 0.6 to 0.9	3	
D. 1.0 or more	4	4
VI. Dissolved Oxygen (percent saturation at 5 ft from surface)		
A. 114% or less	0	0
B. 115% to 119%	1	
C. 120% to 129%	2	
D. 130% to 139%	3	
E. 150% or more	4	

TABLE VII-1 Con't

VII. Dissolved Oxygen (percent of measured water column with at least 0.1 ppm)		
A. 76% or more	0	0
B. 66% to 75%	1	
C. 50% to 65%	2	
D. 29% to 49%	3	
E. 28% or less	4	
VIII. Light Penetration (Secchi disk)		
A. Over five ft	0	
B. Five ft or less	6	6
IX. Light Transmission (percent of light transmission at depth of 3 ft by photocell)		
A. 71% or more	0	
B. 51% to 70%	2	
C. 31% to 50%	3	3
D. 30% or less	4	
X. Total Plankton (per liter of water sampled from a single vertical tow between 1% light level and the surface)		
A. less than 3,000 organisms/L	0	
B. 3,000 to 6,000 organisms/L	1	
C. 6,001 to 16,000 organisms/L	2	
D. 16,001 to 26,000 organisms/L	3	
E. 26,001 to 36,000 organisms/L	4	
F. 26,001 to 60,000 organisms/L	5	
G. 60,001 to 95,000 organisms/L	10	
H. 95,001 to 150,000 organisms/L	15	
I. 150,001 to 500,000 organisms/L	20	20
J. greater than 500,000 organisms/L	25	
K. blue-green dominance add	10 pts.	10
Total		53

B. Carlson's Trophic State Index

The cloudiness of lake water and how far down you can see is often related to the amount of nutrients in the water. Nutrients promote growth of microscopic plant cells (phytoplankton) that are fed upon by microscopic animals (zooplankton). The more the nutrients, the more the plants and animals and the cloudier the water is. This is a common, but indirect, way to roughly estimate the condition of the lake. This condition is a natural aging process of lakes, however it is unnaturally accelerated by too many nutrients.

A secchi disk is commonly used to measure the depth, to which you can easily see through the water, also called its transparency. Secchi disk transparency, chlorophyll a (an indirect measure of phytoplankton), and total phosphorus (an important nutrient and potential pollutant) are often used to define the degree of eutrophication, or trophic status of a lake.
The concept of trophic status is based on the fact that changes in nutrient levels (measured by total phosphorus) causes changes in algal biomass (measured by chlorophyll a), which in turn causes changes in lake clarity (measured by Secchi disk transparency). A trophic state index is a convenient way to quantify this relationship. Dr. Robert Carlson of Kent State University developed one popular index.

Carlson's Trophic State Index uses a log transformation of Secchi disk values as a measure of algal biomass on a scale from 0 - 110. Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll a and total phosphorus are usually closely correlated to Secchi disk measurements, these parameters can also be assigned trophic state index values. The Carlson trophic state index is useful for comparing lakes within a region and for assessing changes in trophic status over time. Thus it is often valuable to include an analysis of trophic state index values in summary reports of a diagnostic study. One limitation is that the Carlson trophic state index was developed for use with lakes that have few rooted aquatic plants and little non-algal turbidity. Use of the index with Brush Creek Reservoir is believed to be appropriate, as those conditions do not apply to the reservoir.

Three relationships have been formulated by Carlson to calculate the index values as follows

$TSI = 60 - 14.41 \ln \text{Secchi disk (meters)}$
$TSI = 9.81 \ln \text{Chlorophyll a } (\mu g/L) + 30.6$
$TSI = 14.42 \ln \text{Total phosphorus } (\mu g/L) + 4.15$

where:

TSI = Carlson trophic state index
ln = natural logarithm

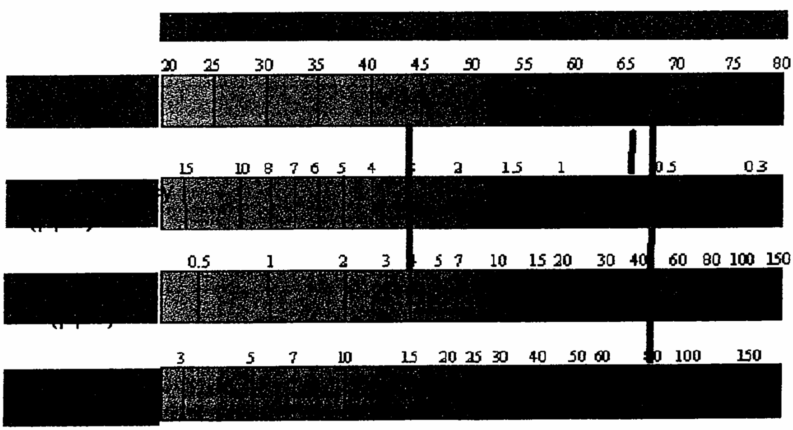
The formulas for calculating the Carlson trophic state index values for Secchi disk, chlorophyll a, and total phosphorus are presented below. Also presented is a graph that lists the trophic state values and the corresponding measurements of the three parameters. Ranges of trophic state index values are often grouped into trophic state classifications. The range between 40 and 50 is usually associated with mesotrophy (moderate productivity). Index values greater than 50 are associated with eutrophy (high productivity). Values less than 40 are associated with oligotrophy (low productivity). Presented below is Carlson trophic state index values for Brush Creek Reservoir. The index based on the chlorophyll-a value is not consistent with indices based on Secchi disk and total phosphorus. Incorrect filters were used to filter the water for the chlorophyll-an analysis, which may have affected the results. As seen from the TSI values, Brush Creek Reservoir can be classified as eutrophic.

Secchi Disk Calculations
Secchi disk = 2.1 feet = 0.65 meters
TSI = 60 - 14.41 (ln Secchi disk (meters))
TSI = 60 - (14.41) (-0.43)
TSI = 66.2

Total Phosphorus
Total Phosphorus (epilimnion) = 80 μg/L
TSI = 14.42 (ln Total phosphorus (μg/L)) + 4.15
TSI = (14.42) (4.38) + 4.15
TSI = 67.3

Chlorophyll a
Chlorophyll a = 4.0 μg/L
TSI = (9.81) (ln Chlorophyll a (μg/L)) + 30.6
TSI = (9.81) (1.39) + 30.6
TSI = 44.2

Figure VII-1 Carlson Trophic Scale



C. Permissible Nutrient Loading

A variety of relatively simple empirical models have been developed since the mid-1960's to predict eutrophication on the basis of phosphorus loadings. The P-loading concept assumes that algal growth is limited by the availability of phosphorus in the water and that increased P, which is derived from sewage discharges and from runoff into lakes and streams, has caused water quality degradation - but the sources are controllable. Typically, these models are used to relate the loadings rates for P into the lake to summer concentrations of phosphorus in the lakewater. Then, other empirical relationships are used that link P to various measures of water quality, such as clarity (Secchi depth), algae and oxygen depletion in bottom waters.

The Canadian limnologist, Richard Vollenweider. He noted that deeper lakes were generally less susceptible to phosphorus pollution than shallower lakes. He compiled loading rates, mean depth and trophic states for a set of hundreds of temperate lakes around the world and then visually drew the lines separating the lakes into categories (oligo-, meso- and eutrophic). These plots, shown below, serve as guidelines to determine acceptable and excessive loading rates of phosphorus based on the mean depth. Oligotrophic lakes are predicted to occur at loadings below the admissible levels, while eutrophic lakes occur above the dangerous or excessive levels and mesotrophic lakes lie between the admissible and dangerous levels.

Vollenweider's plotted curves fit the equations:

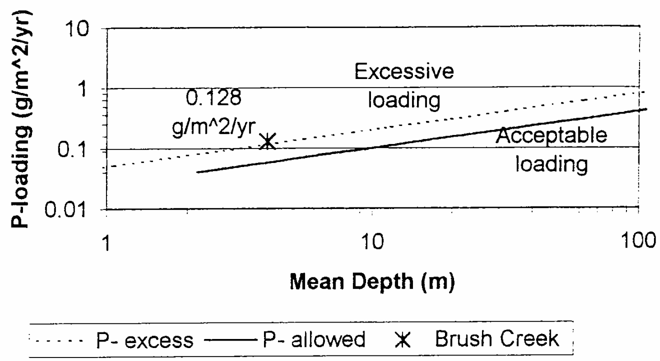
$\text{Log}_{10} P_a = 0.6 \log_{10} H - 1.60$ for admissible loading and

$\text{Log}_{10} P_d = 0.6 \log_{10} H - 1.30$ for dangerous or excessive loading of P

Where H = mean depth.

Phosphorus loading rates, based on concentrations measured in samples collected in August 2001, were calculated in Section IV for Brush Creek. The most downgradient point on the stream (Sample location 5), but above Brush Creek Reservoir, had a P-concentration of 0.059 mg/L as a baseline flow concentration with a flow rate of approximately 1 cfs. Station 5 has a catchment area of approximately 6,300 acres. Applying the conservative loading rate measured during base flow conditions, the calculated Phosphorus loading for the watershed (9,240 acres) is 77.3 Kg/yr. Based on a reservoir size of 149 acres, the area loading is 0.128 $g/m^2/yr$ (1.14 lb/acre/year), which is in the excessive range.

Figure VII-2 Phosphorus Loading vs Vollenweider Phosphorus Loading/Mean Depth Relationship



2. WATERSHED

All activities on earth, both natural and those initiated by man, produce some type of by-product from that activity. Under normal circumstances these by-products, some known as pollutants, are re-cycled back into the environment. Natural environmental processes have the ability to correct an imbalance if given sufficient time. However, if a persistent over-load of a pollutant is allowed to continue, the environment cannot keep up and clean itself.

In the simplest of terms, a pollutant is defined as a substance that tends to elevate the "natural" background of that substance once it gets into the environment. Often times, there may not be significant or any amount of the substance in the environment to start with.

Of greatest concern to this study, are the pollutants that get into Brush Creek from both rural and urban sources or activities. The main six types of pollutants that reduce the quality of surface water include:

- Sediment- associated with wind and water erosion of soils
- Nutrients- from fertilizers, animal wastes, sewage treatment plants.
- Animal wastes- Fecal coliform from livestock and septic systems
- Pesticides- Herbicides, insecticides, fungicides, etc.
- Salt- Mainly from applied road salt
- Toxics- Manufactured and refined products like oil, paints, anti-freeze, etc.

Pollution entering waterways can be divided into two broad types: point and non-point source pollution. Point sources are generally more conspicuous than non-point sources. As the term implies, the source is traceable to a single point of discharge- generally a pipe of other conveyance or outfall structure. Point sources are often regulated by state or federal statutes and permits (i.e. NPDES permits). Examples include municipal wastewater treatment plants; industrial process water discharges, failed or improperly operated septic systems, and feedlots. Non-point sources, on the other hand, are more scattered and far less discernible. Generally, non-point sources of pollution originate from the surface of a watershed- usually associated with man's activity. Examples include amendments applied to agricultural land, erosion from agricultural and construction activities, and exposed industrial activities.

A. Point Sources

Point sources arise from a definite or distinct source such as a wastewater treatment plant, industrial facility, or similar source that discharges through a pipe, conduit, or similar outlet. They are relatively easy to identify by tracing the discharge back to a specific source. Point sources were traditionally considered to be the primary sources of pollution to waterbodies. This is no longer true for most lakes and streams. Harder to identify and harder to control nonpoint sources are more likely to be the principal contributors of nutrient and sediment loads.

B. Nonpoint Sources

One definition used for non-point source pollution is pollutants from a source that is not required to have a National Pollutant Discharge Elimination System (NPDES) Permit. NPDES permits are required for cities, industries, storm water runoff from cities over 100,000 population, storm water runoff from certain industries and animal feedlots with more than 1,000 animal units. Everything left over is a non-point pollutant source.

Non-point source pollutants with the potential to significantly impact Brush Creek include sediments, nutrients, animal waste, and pesticides. These and other materials wash off the land and into the stream directly or they are delivered by tributaries throughout the watershed. Lack of adequate vegetation facilitates the loss of these materials particularly on steep slopes and stream banks. However, even well vegetated lands can become non-point sources when water flow is fast enough to create channels. Inadequately treated wastewater from residential septic systems is also considered a significant non-point source of pollution.

An extensive study of non-point sources of pollution in the Great Lakes Basin was performed by the International Reference Group on Great Lakes Pollution from Land Use Activities (Sonzogni et al., 1980). The results of this study found significant differences in land uses and the potential non-point source pollution generated by each. TableVII-2 is reproduced from that study.

Table VII-2. Ranges of Non-point Source Pollutant Loads by Land Use
(kg/ha/year)
(Source: Sonzogni et al., 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen	Chloride
Rural				
Cropland	20-5100	0.2-4.6	4.3-31	10-50
Improved Pasture	30-80	0.1-0.5	3.2-14	-
Forest	1-820	0.02-0.67	1-6.3	2-20
Idle	7-820	0.02-0.67	0.5-6.0	20-35
Urban				
Residential	620-2300	0.4-1.3	5-7.3	1050
Commercial	50-830	0.1-0.9	1.9-11	10-150
Industrial	450-1700	0.9-4.1	1.9-14	75-160
Developing urban	27,500	23	63	-

Table VII-3. Ranges of Non-point Source Pollutant Loads by Land Use
(lb/acre/year)
(Source: Sonzogni et al., 1980)

Land Use	Suspended Solids	Total Phosphorus	Total Nitrogen	Chloride
Rural				
Cropland	18-4550	0.18-4.1	3.8-28	9-45
Improved Pasture	27-71	0.1-0.4	2.9-12.5	-
Forest	1-730	0.02-0.6	1-5.6	2-18
Idle	6-730	0.02-0.6	0.4-5.4	18-31
Urban				
Residential	550-2050	0.4-1.2	4.5-6.5	940
Commercial	45-740	0.1-0.8	1.7-9.8	9-135
Industrial	400-1517	0.8-3.7	1.7-12.5	67-143
Developing urban	24,500	20	56	-

The results of this study found significant differences in land uses and the non-point pollution they generate. In rural areas, conventional cropping systems can result in exposed soils being vulnerable to erosion with the potential to have elevated levels of suspended solids. However, the table also shows that disturbances associated with construction activities in the development of urban lands can result in significant suspended solids and nutrient loading of runoff from those areas.

Studies of non-point source pollution tend to focus on identifying and quantifying non-point source loads associated with various land uses. However, landform characteristics can have a greater impact on the extent of non-point source pollution than the land use. These characteristics include soil texture, soil type, surficial geology, slope, and soil chemistry and the characteristic having the single most impact on pollution potential is soil texture. Soil texture is defined as the relative proportions or distribution of particles of sand, silt, and clay. Overall, runoff is more prevalent on fine-grained clay soils than on coarse-grained sandy soils. Clay-sized particles are easily suspended, however they settle very slowly. Consequently, the probability of transport over land in sheet runoff is very high. Furthermore, clay soils generally have more associated pollutants due to a higher adsorption capacity, which compounds the situation.

Table VII-4 gives the runoff coefficients (% of precipitation that runs off the surface as opposed to infiltrating the surface) for various common rural surfaces based on cover, soil types, and slope. Runoff increases as the percent slope and clay content increases (Marsh and Borton, 1976).

Table VII-4. Runoff Coefficients for Various Rural Land Uses (Source: Marsh and Borton, 1976)

Topography & Vegetation	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat (0-5% slope)	0.1	0.3	0.4
Rolling (5-10% slope)	0.25	0.35	0.5
Hilly (10-30% slope)	0.3	0.5	0.6
Pasture			
Flat (0-5% slope)	0.1	0.3	0.4
Rolling (5-10% slope)	0.16	0.36	0.55
Hilly (10-30% slope)	0.22	0.42	0.6
Cultivated			
Flat (0-5% slope)	0.3	0.5	0.6
Rolling (5-10% slope)	0.4	0.6	0.7
Hilly (10-30% slope)	0.52	0.72	0.82

It follows then that non-point source pollution and the associated loading to Brush Creek are heavily influenced by land cover and land use. Figure IV-5 presented the distribution of land cover and land use for Brush Creek watershed indicating 48% is cropland. The landuse map shows that the proportions of landuse are not equally divided between the two counties. Over two-thirds of the Brush Creek watershed that is in Ripley County is cropland while less than two thirds of the watershed in Jennings County is used for crop production. Based solely on the proportions of cropland versus forestland, the Ripley County segments of the watershed can be expected to be more significant sources of non-point source pollution than the Jennings County watershed, which is 45%, forested. Beyond that however, landform characteristics also must be considered. In essence, not only is it imperative to examine the trends in land use of the watershed, but also the land form characteristics where those land uses are being applied.

Figure VII-3 presents landuses, on a percentage basis, by subwatershed. In this context, the term subwatershed refers to the contributing drainage area between sampling points- not the entire drainage area above the sample point. For example, sample point 5 is located on Brush Creek and the total watershed at that location is approximately 6,000 acres while at location 6 the watershed is some 5,000 acres. The percentages of the various landuses shown in the table for location 5 are based on the 1,000 acre subwatershed between points 5 and 6- not the entire watershed above point 5. Sample points 4, 5, 6, 8, and 10 are located on Brush Creek and represent water quality

Landuse	Watershed	1	2	3	4	5	6	7	8	9	9U	10
Commercial	0%	4%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water	1%	0%	0%	0%	1%	5%	1%	2%	1%	1%	0%	0%
Residential	3%	1%	6%	2%	2%	3%	2%	3%	3%	4%	10%	2%
Pasture	16%	4%	0%	8%	11%	24%	18%	32%	11%	25%	0%	0%
Forest	32%	91%	65%	55%	46%	35%	44%	24%	12%	7%	0%	13%
Cropland	48%	0%	24%	35%	40%	30%	36%	40%	72%	63%	90%	85%

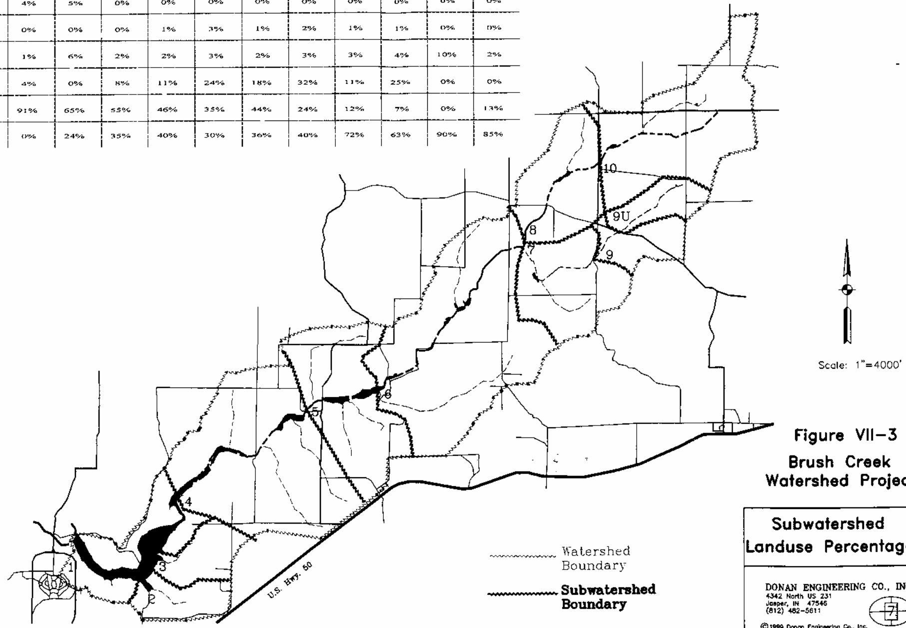


Figure VII-3
Brush Creek Watershed Project

Subwatershed Landuse Percentages

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at various positions in the watershed. Figure VII-4 summarizes how the percentages of cropland increase at each upgradient increment of the watershed. Sample points 7, 9, and 9U show a similar pattern with increased percentages of cropland at the upgradient increments. As stated earlier, landuse decisions are based at least in part on land form characterics and higher percentages of cropland are expected in the flatter regions.

C. Agriculture

The United States has over 330 million acres of agricultural land that produce an abundant supply of low cost, nutritious food and other products. Although American agriculture is noted worldwide for its productivity, quality, and efficiency, improperly managed agricultural activities can have a serious affect on water quality. According to the most recent *National Water Quality Inventory* report, agricultural non-point source pollution is the leading source of water quality impacts to the rivers and lakes surveyed. Agricultural non-point source pollution has also been identified as a major contributor to ground water contamination and wetlands degradation.

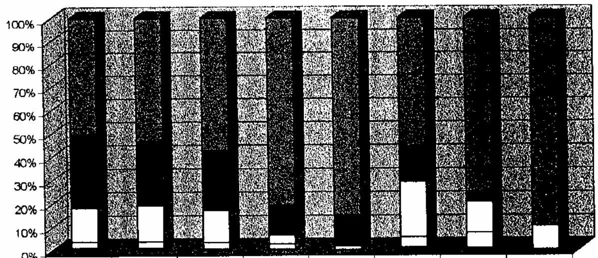
The primary agricultural non-point source pollutants are nutrients, sediment, animal wastes, salts, and pesticides. Agricultural activities also have the potential to directly impact the habitat of aquatic species through physical disturbances caused by livestock or equipment, or through the management of the water resource.

1. Nutrients

Nitrogen (N) and phosphorus (P) are the two major nutrients from agricultural land that degrade water quality. Nutrients are applied to agricultural land in several different forms and come from various sources, including, commercial fertilizer, manure, municipal and industrial treatment plant sludge or effluent, legumes and crop residues, irrigation water, and atmospheric deposition.

The nitrogen and phosphorus levels measured in the various Brush Creek stream samples were evaluated to correlate with landuse trends of the incremental subwatershed. Figure VII-5 summarizes the nitrate/nitrite and Total N concentrations measured in stormwater samples from Brush Creek (points 4, 5, 6, 8, and 10) and the unnamed tributary (points 7 and 9). This data is overlaid onto a bar-graph of the landuse percentages for the incremental subwatersheds. The graph indicates that the highest nitrogen levels were measured in samples taken at location 10 which has the highest percentage of cropland.

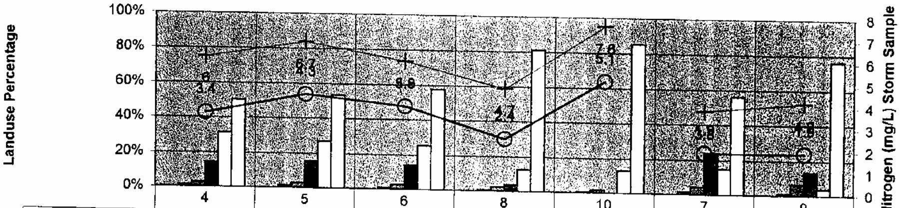
Figure VII-4 Brush Creek Watershed Landuse Percentages at Various Sampling Locations



	4	5	6	8	10	7	9	9U
Cropland	50%	53%	58%	81%	85%	56%	76%	90%
Forest	31%	27%	25%	13%	13%	15%	4%	0%
Pasture	14%	15%	14%	4%	0%	24%	13%	0%
Residential	3%	3%	3%	2%	2%	4%	7%	10%
Water	1%	1%	1%	1%	0%	1%	1%	0%

Sampling Points

Figure VII-5 Brush Creek Watershed Landuse Percentages vs Nitrogen levels



	4	5	6	8	10	7	9
Commercial	0%	0%	0%	0%	0%	0%	0%
Water	1%	1%	1%	1%	0%	1%	1%
Residential	3%	3%	3%	2%	2%	4%	7%
Pasture	14%	15%	14%	4%	0%	24%	13%
Forest	31%	27%	25%	13%	13%	15%	4%
Cropland	50%	53%	58%	81%	85%	56%	76%

Sampling Points

A similar comparison was performed for phosphorus based also on the storm water sampling. That evaluation is presented in Figure VII-6. Total and dissolved phosphorus levels at all stream point locations were similar and elevated above targeted levels. The limited sampling data did not confirm a correlation between phosphorus levels and increases in percentage cropland.

All plants require nutrients for growth. In aquatic environments, nutrient availability usually limits plant growth. N and P generally are present at background or natural levels below 0.3 mg/L N and 0.05 mg/L P. However, when these nutrients are introduced into a stream at higher rates, aquatic plant productivity can increase dramatically. This adds more organic material, which eventually dies and decays. The decaying organic matter produces unpleasant odors and depletes the oxygen supply required by aquatic organisms. Depleted oxygen levels can reduce the quality of fish habitat and encourages the propagation of fish that are adapted to less oxygen.

Highly enriched waters will stimulate algae production, with consequent increased turbidity and color. This results in less sunlight penetration and availability to submerged aquatic vegetation that provides habitat for small fish. The loss of this submerged aquatic vegetation can have a severe impact to the food chain.

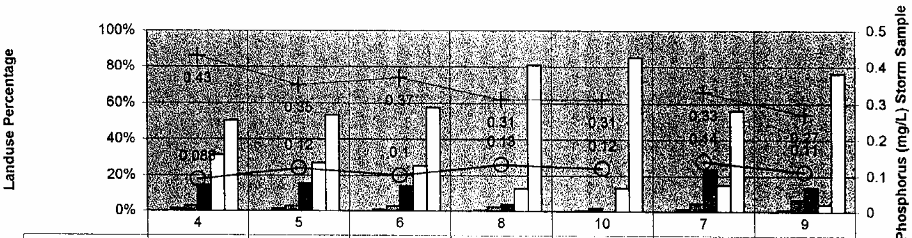
2. Sediment

Sediment affects the use of water in many ways. Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, clog the filtering capacity of filter feeders, and clog and harm the gills of fish. Turbidity interferes with the feeding habits of fish and chemicals such as pesticides, phosphorus, and ammonium are transported with sediment and in adsorbed state.

Soil eroded and delivered from cropland as sediment usually contains a higher percentage of finer and less dense particles than the parent soil on the cropland. This change in composition of eroded soil is due to the selective nature of the erosion process. Larger particles are more readily detached from the soil surface because they are less cohesive, but they also settle out of suspension more quickly because of their size. Organic matter is not easily detached because of its cohesive nature, but once detached it is easily transported because of low density. Clay particles and organic residues will remain suspended for longer periods and at slower flow velocities than larger more dense particles. This selective erosion process can increase overall pollutant delivery per ton of sediment delivered because small particles have a much greater adsorption capacity than larger particles. As a result, eroding sediments generally contain higher concentrations of P, N, and pesticides than the parent soil from which they were eroded.

Natural processes such as the production of soil occur at an alarmingly slower rate than soil can be lost. It is estimated that over 3 billion metric tons of soil are eroded off of our fields and pastures each year by water erosion alone. The main variables affecting water erosion are precipitation and surface runoff. Raindrops, the most common form of precipitation, can be very destructive when they strike bare soil. With impacts of over 20 mph, raindrops splash grains of soil into the air and wash out seeds. Overland flow, or surface runoff, then carries away the detached soil, and may detach additional soils and then sediment, which can be, deposited

Figure VII-6 Brush Creek Watershed Landuse Percentages vs Phosphorus levels



	4	5	6	8	10	7	9
Commercial	0%	0%	0%	0%	0%	0%	0%
Water	1%	1%	1%	1%	0%	1%	1%
Residential	3%	3%	3%	2%	2%	4%	7%
Pasture	14%	15%	14%	4%	0%	24%	13%
Forest	31%	27%	25%	13%	13%	15%	4%
Cropland	50%	53%	58%	81%	85%	56%	76%

Sampling Points

elsewhere. Sheet and interrill erosion are mainly caused by rainfall. However, some of the more severe erosion problems such as rill erosion, channel erosion, and gully erosion all result from concentrated overland flow.

When fertile soil is removed, along with it go the nutrients and organic matter, which are significant to the growth of plants and crops. Without this soil, plants and crops will not survive. Thus, it's easy to see that a reduction in this protective cover will only expose more soil to the detrimental effects of wind and water erosion. In addition to the use of conservation tillage to control sheet and rill erosion, there are several other control practices, which are available. In particular, vegetated waterways can be very important in small watersheds in which water flows from hillslopes concentrate in natural drainageways, and can cause significant gullying.

Much of the cropland in the Brush Creek watershed involves soils in the Cobbsfork-Avonburg map unit, which is characterized by broad ridgetops that are nearly flat with shorter side slopes adjacent to the drainageways. The Cobbsfork soil unit is found in Ripley County while the equivalent in Jennings County is Clermont silt loam. While these soils are well suited to crop production, the long gradual slopes can result in runoff that is very erosive to these side slopes.

A powerful computer simulation model for water erosion prediction has been developed by the United States Department of Agriculture. This model, known as WEPP (Water Erosion Prediction Project), can simulate erosion processes and their interaction with management practices, to predict water erosion under varied scenarios. This can provide planners and farm operators with useful information to aid them in making wise land management decisions.

To accurately predict erosion, WEPP requires the user to specify erodibility values for different soil types. In WEPP, two major components of water erosion have been identified: rill erosion (erosion by water flowing in small channels) and interrill erosion (erosion by raindrop impact and sheet flow). WEPP assigns each soil a set of erodibility parameters, which represent the sensitivity of that soil to rill and interrill erosion. The model has been employed to predict sediment loss from a typical slope profile of the Cobbsfork-Avonburg soil map unit. Although the model has impressive capabilities, the simulation was limited to a hypothetical one-year period for cropland that is used in continuous corn and soybean production with conventional spring chisel plow tillage. The following table and graph summarize the modeling results.

Inputs were taken from information in the Soil Survey of Ripley County and Part of Jennings County, Indiana. The profile represents a 200-foot wide band of cropland that extends perpendicular to the drainageway approximately 1,100 feet. For the purposes of this modeling, the cropland is considered to be uninterrupted. While these conditions may appear to represent an extreme scenario, the soil units, segment lengths, and slopes were taken directly from the soil survey.

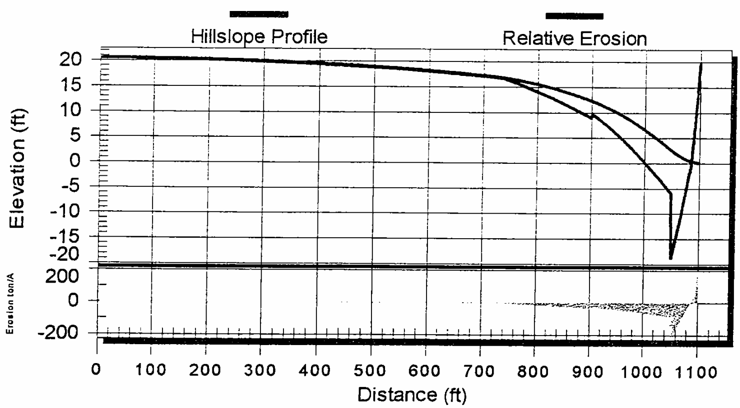
Table VII-5
Brush Creek Cropland
Typical Erosion

Average Annual Precipitation 43.00 in
Average Annual Runoff 2.30 in
Average Annual Soil Loss 14.800 ton/A
Average Annual Sediment Yield 13.400 ton/A

Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
corn-spring chisel plow	1095.0	14.79	1086.0	62.44	9.0
corn-spring chisel plow	5.0	0.00	0.0	160.21	5.0

Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.89	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.25	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	54.54	150.0	0.00	0.0
IN\ HOLTON(SIL)	50.0	109.53	36.0	97.36	14.0

Figure VII-7 Typical Cropland Erosion Profile



3. Animal Wastes

Manure includes the fecal and urinary wastes of livestock and poultry, process water (such as from a milking parlor), and the feed, bedding, litter, and soil with which they become intermixed. Pollutants that are contained in manure and associated bedding materials can be transported by runoff water and process wastewater from confined feeding facilities. These pollutants generally include oxygen-demanding substances, N, P, other nutrients, organic solids, salts, undesirable organisms, and sediments.

Dissolved oxygen depletion brought on by oxygen-demanding substances and decaying organic materials delivered to surface waters can result in extensive fish kills which has a compounding effect by adding even more organic material for decay in a stream.

In addition, animal diseases can be transmitted to humans through contact with animal feces. Runoff from fields receiving manure will contain extremely high numbers of bacteria if the manure has not been incorporated into the soil or the bacteria have not been subject to lethal stress. The method, timing, and rate of manure applications are significant factors in determining the likelihood that water quality contamination will result. Manure is generally more likely to be transported in runoff when applied to the soil surface than when incorporated into the soil. Spreading manure on frozen ground or snow can result in high concentrations of nutrients being transported from the field during rainfall or snowmelt, especially when the snowmelt or rainfall events occur soon after spreading.

Manure applied to idle cropland can be incorporated into the soil by discing or other primary tillage. The farmer applying manure to pasture or hayland must rely on timing and apply at an appropriate rate to better utilize this resource and reduce the impacts to surface water. Typically, application rates of manure for crop production that are based on N, exceed plant requirements for P and K. The soil generally has the capacity to adsorb P leached from manure applied on land if infiltration occurs. Nitrates, however, are easily leached through the soil into ground water and both phosphorus and potassium can be transported by eroded soil.

4. Salts

Salts are a product of the natural weathering process of soil and geologic material. They are present in varying degrees in all soils and in fresh water and ground water. In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs.

High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops. Salts become concentrated in the soil through a process referred to as the "concentrating effect". That is, as soil water is consumed by plants or lost to the atmosphere by evaporation, the salts remain. This process especially becomes significant in irrigation systems where irrigation return flow carries a salt load that increases as it is circulated through an irrigation system. Large-scale irrigation systems are not utilized in the Brush Creek watershed.

5. Pesticides

The term *pesticide* includes any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or intended for use as a plant regulator, defoliant, or desiccant. The principle pesticidal pollutants that may be detected in surface waters and in ground water are the active and inert ingredients and any persistent degradation products. Despite the documented benefits of using pesticides to control plant pests and enhance production, these chemicals may cause impairments to the uses of surface water and ground water. Some types of pesticides are resistant to degradation and may persist and accumulate in aquatic ecosystems.

Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species. Less than lethal effects include the behavioral and structural changes of an organism that jeopardizes its survival. Bioconcentration is a phenomenon that occurs if an organism ingests more of a pesticide than it excretes. During its lifetime, the organism will accumulate a higher concentration of that pesticide than is present in the surrounding environment. When the organism is eaten by another animal higher in the food chain, the pesticide will then be passed to that animal, and on up the food chain to even higher level animals.

The primary routes of pesticide transport to aquatic systems are: direct application, runoff, aerial drift, volatilization and subsequent atmospheric deposition, and uptake by biota and subsequent movement in the food web. Pesticide losses are generally greatest when rainfall is intense and occurs shortly after pesticide application; a condition for which runoff and erosion losses are also greatest.

D. Livestock Grazing

1. Riparian Impacts

Livestock grazing on pasturelands can contribute to nonpoint source pollution in streams. Documentation shows that cattle, given the opportunity, will spend a disproportionate amount of time in a riparian area as compared to drier upland areas. This may be 5 to 30 times higher than expected based on the extent of the riparian area. Features that contribute to higher use levels in riparian areas are:

- Higher forage volume and relative palatability in the riparian area as opposed to the uplands,
- Distance to water,
- Distance upslope to upland grazing sites, and
- Microclimatic features.

Effects of Livestock Grazing

The direct effects of livestock grazing have been summarized as follows:

- Higher stream temperatures from lack of sufficient woody streamside cover,
- Excessive sediment in the channel from bank and upland erosion,
- High coliform bacteria counts from upper watershed,

- Channel widening from hoof-caused bank sloughing and later erosion by water,
- Change in the form of the water column and the channel it flows in,
- Change, reduction, or elimination of vegetation,
- Elimination of riparian areas by channel degradation and lowering of the water table,
- Gradual stream channel trenching or braiding depending on soils and substrate composition with concurrent replacement of riparian vegetation with less desirable plant species.

In an extensive review of livestock impacts on riparian ecosystems, Oregon State University researchers documented many factors interrelated with grazing effects, primarily dealing with instream ecology, terrestrial wildlife, and riparian vegetation. However, as with many others, the authors were not able to find much information other than that abusive grazing practices are damaging to many features of riparian ecosystems. Little information is available on how well managed grazing affects riparian-stream systems. Criticisms of conventional grazing systems such as rest-rotation typically contain no information on actual grazing intensity or degree of plant utilization.

Permanent removal of grazing will not guarantee maximum herbaceous plant production. Researchers found that a protected Kentucky bluegrass meadow reached peak production in six years and then declined until production was similar to the adjacent area grazed season-long. Similar results were reported in northeastern Oregon. The accumulation of litter over a period of years seems to retard herbage production in wet meadow areas. Thus, some grazing of riparian areas could have beneficial effects to plant production.

While vegetation recovery after release from excessive grazing generally can occur within 5 to 15 years, impacts on fishery environments go far beyond the riparian vegetation. Channel and bank morphology, instream cover, and water flow regimens are important factors. Little is known about the recovery time for these factors in different environments. Some researchers have suggested that sediment delivery to the stream was the most detrimental impact of trampling to fisheries. Others, however, pointed out that the retention of bank morphology and stability are probably more important. The maintenance of streambank structure and function is a key item in riparian-stream habitats from both fisheries and hydrologic standpoints. Fisheries biologists suggest several conditions for optimum fish habitat:

- At least 60 percent of the stream shaded between 10 a.m. and 4 p.m. during summer months.
- At least 80 percent of the streambank in stable condition.
- Not more than 15 percent of the gravel/rubble substrate covered by inorganic sediment.
- At least 80 percent of site potential for grass-forb, shrub, and tree cover.
- Instream cover should be about 50 percent of the total stream area.
- Overhanging banks on at least 50 percent of the streambanks.

Vegetation plays a dominant role not only in the erosional stability of streambanks but also in the rebuilding of degraded streambanks. Streamside vegetation serves as a natural trap to retain sediments during high flows. These sediments form the physical basis for new bank structure.

2. Manure Loading into Streams from Direct Fecal Deposits

Although sediment is generally considered the largest water quality problem from livestock grazing, nutrients and pathogens may also be of concern. The major nutrients coming from cattle are:

- nitrogen (N),
- phosphorus (P),
- and potassium (K).

The relatively benign Fecal Coliform (FC), and Fecal Streptococci (FS) bacteria are used to indicate the presence of possible pathogens.

To be considered a pollutant, nutrients and pathogens must reach a stream. Nutrients and pathogens can reach the water either by direct deposit or by overland transport during a runoff event. In most semi-arid environments runoff events are infrequent. Therefore, direct deposit of manure and urine into streams seems to be the most likely mode of nutrient or pathogen loading by livestock. The potential for this mode of contamination depends on time, density, and access.

The amount of time that livestock spend in or near streams can be variable as shown by studies at the San Joaquin Experimental Range (SJER) in the foothills of the Sierra Nevada Mountains in California and in Eastern Oregon (Table 1). The difference in drinking time in Table VII-6 may be that cattle drank from a trough at the SJER, and from streams in Eastern Oregon.

Table VII-6. Amount of time beef cattle spent drinking water as recorded in studies in California and Eastern Oregon.

Author	Drinking Time min/cow/day	Location
Wagnon 1963	3 to 6	SJER, California
Sneva 1970	17	Eastern Oregon
McInnis 1985	26	Eastern Oregon

In 1989, Oregon researchers observed the daily fecal deposits and amount of time spent in the creek by different classes of cattle and during different seasons in a high desert stream in Central Oregon (Table VII-7). They found that time spent in the creek and direct fecal deposits varied by season. This perennial stream is one to three feet wide and ½ to three feet deep. It is characterized by 100 to 300 yard wide riparian zones and bottomland stringer meadows with slopes generally less than five percent dominated by Kentucky bluegrass with some alfalfa and clover. During the winter months some meadows were used for supplemental feeding areas. These meadows and riparian areas were part of a larger pasture that included uplands with 10 to 40 percent slopes consisting of juniper woodlands, sagebrush, and bunch grass. These uplands were dry and relatively unpalatable by early to mid summer.

Table VII-7. The amount of time cattle spent in the stream and the number of defecations directly into a high desert stream in central Oregon. Time in the stream includes drinking, loafing, etc. (From Larsen 1989)

Season	Cattle Class	# of Animals	Time Spent in Stream min/cow/day	Instream Fecal Deposit def/cow/day
Summer	cow/calf	17	11.2	0.41
Fall	cow/calf	18	3.0	0.19
Fall	bull	19	2.3	0.00
Winter	cow	109	5.6	0.20
Winter	yearling	40	0	0.14
Spring	cow/calf	116	3.9	0.17
Average		**5.2**	**0.19**	

Based on non-replicated observations for a two-day period within each season. These values may not be applicable to other streams or grazing regimes and should be verified by further research.

Table VII-8. Estimates of the amount of manure, fecal coliform (FC), fecal streptococci (FS), nitrogen (N), phosphorus (P), and potassium (K) getting into the stream from grazing cattle based on one 1,000 lb beef cow.

Season	Manure			Bacteria		Nutrients	
Per Day	wet+(lb)	dry(lb)	FC(no.)	FS(no.)	N(lb)	P(lb)	K(lb)
Summer	2.05++	0.25	$1.3*10^9$	$2.4*10^7$	0.012	0.004	0.008
Fall	0.95++	0.11	$6.0*10^8$	$1.1*10^7$	0.005	0.002	0.004
Winter	1.00++	0.12	$5.4*10^8$	$1.2*10^7$	0.006	0.002	0.004
Spring	0.85++	0.10	$5.4*10^8$	$1.0*10^7$	0.005	0.002	0.003

+88% water

++Based on non-replicated observations for a two-day period within each season.

This analysis was conducted by range scientists to obtain a rough idea of fecal pollution risk from livestock. These estimates are based on average defecation rates, nutrient contents, and bacteria concentrations in manure and may not reflect the real rates and contents at the site and time of the study.

The fecal loading rate of grazing cattle depends on the amount of time the cattle are grazing in a pasture with a stream. Using the values in Table VI-7 with estimates of defecation rates, nutrient content, and bacteria concentration in manure (Table VI-8), the potential nutrient and bacterial loading directly into the stream was estimated. The amount of manure, nitrogen (N), phosphorus (P), potassium (K), fecal coliform (FC) and fecal streptococci (FS), produced by beef cattle. Based on one 1,000 lb. beef cow.

- 12 defecations/day
- 60 lbs manure/day (88% water)
- 5 lbs manure/defecation (88% water)

- 0.34 lb N/day
- 0.11 lb P/day
- 0.24 lb K/day
- $3.84*10^{10}$ FC/day
- $7.2*10^{8}$ FS/day

Sources: Johnstone-Wallace and Kennedy 1944
Moore and Willrich 1982
Moore et al. 1988

The estimates in Table VII-8 indicate that the amount of manure loading into a stream for any given day, season, or year from one cow is quite small. However, there may still be a concern about pollution. As much as 95% of deposited manure will settle to the bottom of the stream within the first 50 meters (Biskie et al. 1988). The bacteria in the sediment may remain alive for several weeks (Sherer et al. 1992). Less is known about what happens to the nutrients that enter the stream in the manure.

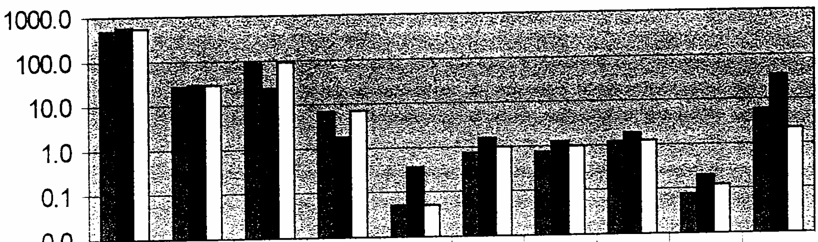
Therefore, daily inputs from directly deposited feces may accumulate on the stream bottom. Any disturbance, such as peak flows, can resuspend sediment, creating high concentrations of bacteria, and possibly nutrients for a short period of time. The higher the density of livestock, the higher the concentration of pollution.

During the sample collection for baseline sampling, beef cattle were observed to have direct access to the tributary of Brush Creek at the location of sample point #9. Samples were collected from the pre-determined location with a herd of cattle in the stream at the time and location of sampling. Since sampling was performed in late summer, the cattle continued to loiter in the stream and did not seem to be disturbed by the sampling activity. A decision was made to add a sample point up stream of the area occupied by the cattle. This field decision was made to exploit the direct and immediate impact of cattle in a stream by characterizing water quality in a before and after setting.

Figure VII-8 shows that many of the parameters are impacted. The average values in the graph represent averages of sample locations 5-8, 9U, 10, and 11 for the select parameters. Sample location 9, due in part to its proximity to the county road intersecting the stream, was regarded as a highly visible stream where livestock access was easily documented. Other locations also were observed to have areas allowing livestock access to the stream.

Samples collected from location #9, compared to location #9U immediately upstream and averages of other locations, had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, slightly elevated temperature and conductivity readings, and elevated levels of Ammonia N, TKN, Organic N, Total N, Total P, and turbidity.

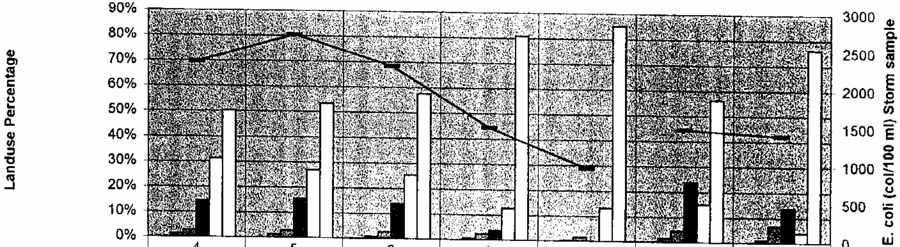
Figure VII-8
Brush Creek
Sample Location 9 vs Averages vs Upgradient Select Parameters



	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Turbidity (NTU)
Average	484.6	26.0	85.8	6.6	0.1	0.7	0.7	1.2	0.1	5.9
9	560	28.9	23.2	1.76	0.36	1.6	1.24	1.85	0.2	34
9U	530	28	89	6.8	0.05	0.96	0.96	1.22	0.12	2.2

During storm sampling in June of 2001, E. coli samples were also collected and this data was presented in Figure V-28. Figure VII-9 presents the E. coli counts at the stream sample locations along with the relative landuses of the subwatersheds. There is an apparent trend as the E.coli count was lowest at point 10, where percent pasture was the lowest. At sample points 4, 5, and 6, where pasture constitutes 14-15% of the landuse, E. coli counts were the highest observed. These counts do not necessarily indicate cattle are directly accessing the streams however there does appear to be a correlation between the pasture landuse percentage and the coliform counts.

Figure VII-9 Brush Creek Watershed Landuse Percentages vs E. coli



	4	5	6	8	10	7	9
Commercial	0%	0%	0%	0%	0%	0%	0%
Water	1%	1%	1%	1%	0%	1%	1%
Residential	3%	3%	3%	2%	2%	4%	7%
Pasture	14%	15%	14%	4%	0%	24%	13%
Forest	31%	27%	25%	13%	13%	15%	4%
Cropland	50%	53%	58%	81%	85%	56%	76%
E. coli	2320	2680	2280	1480	960	1480	1400

Sampling Points

E. Silviculture Managing Nonpoint Source Pollution from Forestry

Nearly 500 million acres of forested lands are managed for the production of timber in the United States. Although only a very small percentage of this land is harvested each year, forestry activities can cause significant water quality problems if improperly managed. The latest National Water Quality Inventory reports that forestry activities contribute to approximately 9 percent of the water quality problems in surveyed rivers and streams.

Sources of NPS pollution associated with forestry activities include removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for the planting of trees. Road construction and road use are the primary sources of NPS pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations. Harvesting trees in the area beside a stream can affect water quality by reducing the streambank shading that regulates water temperature and by removing vegetation that stabilizes the streambanks. These changes can harm aquatic life by limiting sources of food, shade, and shelter.

1. Preharvest Planning: Opportunities to Prevent NPS Pollution

To limit water quality impacts caused by forestry, public and private forest managers have developed and followed site-specific forest management plans. Following properly designed preharvest plans can result in logging activities that are both profitable and highly protective of water quality. Such plans address the full range of forestry activities that can cause NPS pollution. They clearly identify the area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction, and maintenance, as well as for harvesting methods and forest regeneration.

Public meetings held under the authority of federal and state laws provide citizens with a good opportunity to review and comment on the development of forest management plans.

Preactivity surveys can help identify areas that might need special protection or management during forestry operations. Sensitive landscapes usually have steep slopes, a greater potential for landslides, sensitive rock formations, high precipitation levels, snowpack, or special ecological functions such as those provided by streamside vegetation. Forestry activities occurring in these areas have a high potential of affecting water quality.

Because most forestry activities disturb soil and contribute to erosion and runoff, timing operations carefully can significantly reduce their impact on water quality and aquatic life. Rainy seasons and fish migration and spawning seasons, for example, should be avoided when conducting forestry activities.

2. Establishing Streamside Management Areas (SMAs)

Plans often restrict forestry activities in vegetated areas near streams (also known as buffer strips or riparian zones), thereby establishing special SMAs. The vegetation in a SMA is highly beneficial to water quality and aquatic habitat. Vegetation in the SMA stabilizes streambanks, reduces runoff and nutrient levels in runoff, and traps sediment generated from upslope activities before it reaches surface waters. SMA vegetation moderates water temperature by shading surface water and provides habitat for aquatic life. For example, large trees provide shade while alive and provide aquatic habitat after they die and fall into the stream as large woody debris.

3. Managing Road Construction, Layout, Use, and Maintenance

Good road location and design can greatly reduce the transport of sediment to water bodies. Whenever possible, road systems should be designed to minimize road length, road width, and the number of places where water bodies are crossed. Roads should also follow the natural contours of the land and be located away from steep gradients, landslide-prone areas, and areas with poor drainage. Proper road maintenance and closure of unneeded roads can help reduce NPS impacts from erosion over the long term.

4. Managing Timber Harvesting

Most detrimental effects of harvesting are related to the access and movement of vehicles and machinery, and the dragging and loading of trees or logs. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels. Poor harvesting and transport techniques can increase sediment production by 10 to 20 times and disturb as much as 40 percent of the soil surface. In contrast, careful logging disturbs as little as 8 percent of the soil surface. Careful selection of equipment and methods for transporting logs from the harvest area to areas where logs are gathered can significantly reduce the amount of soil disturbed and delivered to water bodies. Stream channels should be protected from logging debris at all times during harvesting operations.

5. Managing Replanting

Forests can be regenerated from either seed or seedlings. Seeding usually requires that the soil surface be prepared before planting. Seedlings can be directly planted with machines after minimal soil preparation. In either case, the use of heavy machinery can result in significant soil disturbance if not performed carefully.

F. Septic Systems

Sanitary sewers are not found in the Brush Creek watershed, forcing residents to use on-site sewage disposal systems, according to the Jennings County and Ripley County Health Departments. These disposal systems can work well in disposing of sewage, but when installed improperly or placed in poor geologic conditions, septic systems may have negative environmental impacts. Within the Brush Creek watershed, Jennings County Sanitarian Mary Wilkerson reports that the rural areas of the county are plagued with failed septic systems. In many cases, absorption fields have been expanded to include all areas available and lot sizes are a limitation. Most failed systems stem from inherent soil properties that are simply not suitable for conventional on-site sewage disposal. Ms. Wilkerson stated that residents in Campbell Township attempted to pursue sanitary sewer service some years ago. The effort involved plans for sewer service to the rural areas plus updated service for the Muscatatuck Development Center, currently operating their own treatment system. That endeavor was not successful. Figure VII-10 maps the locations of homes in the Brush Creek watershed presumed to have septic tank systems of some sort.

Ripley County Sanitarian Andy Bryant stated in a phone interview that Ripley County also has an abundance of failed septic systems. They also have expanded disposal fields of failed systems and require large fields with reduced loading rates for new installations. The community of Holton, south of the Brush Creek watershed has sanitary sewer service however Mr. Bryant was doubtful that sewer service would be extended into the rural areas in the foreseeable future.

Approximately 1/3 of all homes in the United States dispose of their wastewater through septic systems, and about 25 percent of all new homes include septic tanks. Septic systems have been identified as local and regionalized sources of groundwater pollution and nonpoint source pollution to surface waters. The major pollutants associated with septic systems are nitrates and bacteria. Where sewers are not available, septic systems are usually the only alternative. Where traditional septic systems cannot be installed due to site constraints, there are alternatives such as low pressure dosing and sand filters. However these alternative methods are more expensive than the traditional septic system.

1. Septic Tank/Drainfield

The most common type of onsite sewage treatment system is the septic tank/drainfield system. Septic tank systems have made possible relatively high-density residential development in areas where municipal wastewater treatment facilities are not available. The main function of the tank is to remove the solids from the wastewater. The water that enters the tank enters from a pipe that is connected to the home's main drain. Heavier solids settle to the bottom of the tank and pile up to create sludge. Lighter solids, like grease, float on the surface and form a mat of scum. Bacteria in the tank digest a vast amount of the heavier solids and grease. During this decomposition, some solids are liquefied and leave the tank with the wastewater; thereby reducing the volume of the solids retained in the tank.

The remaining solids that accumulate in the tank must be pumped out of the tank at regular intervals. A recommended time interval for pumping is once about every three to five years. A properly designed and maintained tank should last 50 years or more.

2. Legal Aspects of Septic Tanks

The Health Departments of Jennings and Ripley Counties are responsible for permitting septic systems in the Brush Creek watershed. Homeowners must have a site evaluation and a permit from the health department to build or modify a septic system. A property must meet the standards set forth before a permit is issued. Homeowners can be prosecuted for installing a sewage disposal system without a health department operation permit. Failure to abide by this regulation may result in a misdemeanor conviction or, in certain instances, more serious charges.

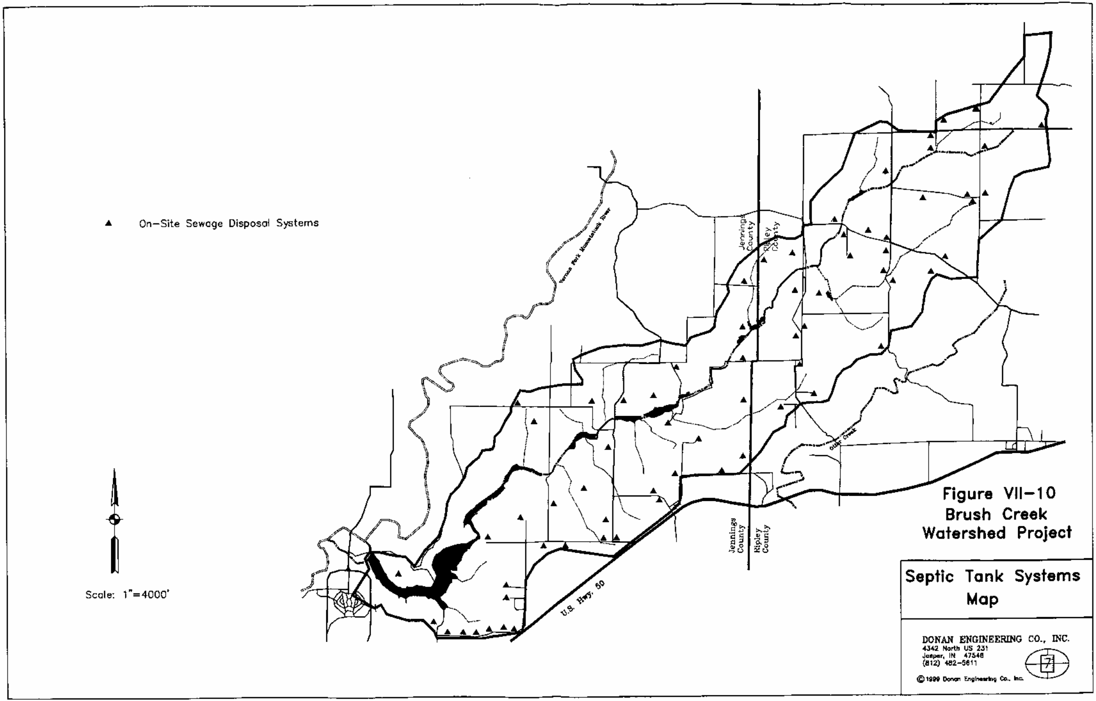


Figure VII-10
Brush Creek
Watershed Project

Septic Tank Systems
Map

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Any agreement with a septic system installation firm should have a stipulation stating that no payment is given until the system passes inspection by the sanitation. The State of Indiana has regulations regarding the location of septic systems in relations to boundaries, wells and homes. The septic tank and drainfield must not be located under a patio, garage, storage building, parking lot, or other paved area.

3. Pollution from Septic Systems

A major concern with the design and usage of septic systems is the potential of polluting the groundwater. Pollution could come from metals, microbes, or other substances. The volume of water that flows into an average septic tank is on the order of 140 to 150 gallons per day per person. This amount can be broken down into percentages from typical household sources. On a percentage basis the sources can be broken down as follows:

Table VII-9 Typical Septic Tank Inflows	
Activity	Percentage
Toilets	22-45%
Laundry	4-26%
Baths	8-37%
Kitchen	6-13%
other sources	0-14%.

4. Efficiency of Soil Adsorption

The efficiency of soil adsorption is how much various parameters in the effluent from the septic tank are reduced compared to the influent. Many factors are involved in the efficiency of soil adsorption. Such factors as climate, soil type, hydraulic conductivity, precipitation, porosity, etc. contribute to how the effluent concentration is reduced in the soil.

A field study was conducted from December 1972, to February 1974 in Ottawa, Ontario, Canada by Viraraghavan and Warnock. Soil samples were taken from various depths. From a 5 ft deep area of the underlying soil the following was found:

- Soil was able to reduce 75-90% of the soluble organic carbon, Total Soluble Solids (TSS), Biological Oxygen Demand (BOD), and the Chemical Oxygen Demand (COD)
- The levels of phosphate were reduced on the order of 25-50%.
- High reductions in ammonia were found (80-90%)
- The changing seasons had a noticeable effect on efficiency of the system. Greater efficiencies (80-90%) were observed during the late summer and early fall. This period was when the unsaturated depth of soil was the greatest. These efficiencies tended to decrease during the winter period when water levels in the soil began to rise. Decreases to 70-75% were observed for BOD and TSS and 20-35% for ammonia.

5. Groundwater Contamination

Groundwater contamination has occurred where there have been high densities of septic systems. Studies have shown that the groundwater has been contaminated by high amounts of organic contaminants from septic systems. Problems with septic systems are greater when communities that rely on subsurface disposal systems also depend on private wells for drinking water. As many as one-half of all septic tanks in operation are not functioning correctly. A common failure of a system is when the capacity of soil to absorb effluent is exceeded. When this occurs, the wastewater from the drain lines makes its way to the surface. This type of failure occurs when the soil is clogged with waste particles or other substances and it is harder for the water to move through the soil. When the system fails in this way and wastewater makes its way to the surface, water runoff from rain may wash the contaminants into surface waters or into inadequately sealed wells down gradient.

A more significant failure is when pollutants from the drain field move too quickly through the soil and potentially into the groundwater. When there is large volume of wastewater moving through the system, soils with high permeability can be rapidly overloaded with organic and inorganic chemicals and microbes, allowing rapid movement of pollutants into the groundwater. Special attention must be directed to the transport and fate of pollutants in the soil absorption phase when considering contamination of groundwater from septic systems.

Suspended solids in the effluent from the septic system are removed by filtration as the wastewater moves through the soil. This process of filtration varies with the soil type, the size of the particles, soil texture, and the rate of the water flow. The key chemical processes governing the movement of particles from the effluent through the soil are ion exchange, adsorption, and chemical precipitation.

a. Inorganic Contaminants

Some potential inorganic contaminants from septic systems include nitrogen, chlorides, phosphorous, and metals.

Nitrogen

The organic form of nitrogen is converted to the ammonium form since anaerobic conditions occur in the septic tank. The amount of nitrogen in the effluent from the tank averages about 40 mg/L and consists roughly of 75% in the NH_4^+ and 25% in the organic form. Nitrogen contamination is of concern because it causes eutrophication in surface waters and is hazardous to human health if ingested in high concentrations. The fate and movement of nitrogen in the soil from septic systems is dependent on the form of the nitrogen and biological conversions that may take place. The most common form of nitrogen entering the soil, ammonium (NH_4^+) form, undergoes the process of nitrification. In the process of nitrification, ammonium is converted to nitrite and then into nitrate (NO_3^-). This process is an aerobic reaction carried out by obligate autotrophic organisms.

Denitrification also occurs in the soil under the septic system. Denitrification is the reduction of NO_3^- to N_2O or N_2 by obligate facultative heterotrophs. In the absence of O_2, NO_3^- acts as the acceptor of electrons generated in the microbial decomposition of an energy source. Since ammonium is the most common form of nitrogen present, nitrification must occur before denitrification can. Nitrate NO_3^- is the most mobile form of nitrogen in both saturated and unsaturated soil conditions. The immobilization of nitrates is done by the uptake of it by plants in the immediate area. The nitrates move with water with little transformation and can travel long distances if the right conditions are present.

Chlorides

Chlorides are very common and are naturally present in surface and groundwater, and are also found in wastewaters. Chlorides are difficult to remove from wastewaters and both septic systems and wastewater treatment plants are unable to remove them. The concentration of chlorides in wastewater varies with the natural quality of the water supply. Since chlorides are anionic and mobile, they can be used as tracers of septic tank system pollution. (Canter & Knox)

Phosphorus

Most of the influent phosphorus in the organic and phosphate forms is converted to soluble orthophosphate by the anaerobic process occurring in the septic tank. Usually phosphorus does not reach the groundwater because it is strongly retained in soils. Phosphorus is not really harmful to humans but it is a major contributor to eutrophication in surface waters.

b. Other Inorganic Contaminants

Metals in the effluents from septic tank systems may be responsible for the contamination of shallow water supply sources, such as where there is a high groundwater table. In some areas, the levels of arsenic, iron, lead, mercury, and manganese were found at levels higher than what is recommended.

The soil type is an important factor in all heavy metal fixation reactions. Both soil texture and pH are important in the fixation of metals by the soil. Finer textured soil immobilizes trace and heavy metals to a greater extent as compared with those with coarse texture. Finer textured soils usually have a greater action exchange capacity due to their larger surface area. The transport of lead, zinc, mercury, and nickel has been linked to the texture of soil. The degree of fixation is a function of the pH. Soil pH influences the immobilization of lead, mercury, copper, and zinc.

c. Microorganisms

Microorganisms usually do not contaminate groundwater sources. The main limitation to movement of microbes through the soil is the physical filtration of bacteria and other microbes. It is the factor that usually limits the travel distances. Soil conditions such as no nutrients, drying, and antagonistic organisms' secretions also determine the travel distances.

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VIII. ALTERNATIVES

1. Agricultural BMPs

The United States has over 330 million acres of agricultural land that produce an abundant supply of low-cost, nutritious food and other products. American agriculture is noted worldwide for its high productivity, quality, and efficiency in delivering goods to the consumer. However, when improperly managed, agricultural activities can affect water quality. The most recent National Water Quality Inventory reports that agricultural nonpoint source (NPS) pollution is the leading source of water quality impacts to surveyed rivers and lakes, the third largest source of impairments to surveyed estuaries, and also a major contributor to ground water contamination and wetlands degradation.

Agricultural activities that cause NPS pollution include confined animal facilities, grazing, plowing, pesticide spraying, irrigation, fertilizing, planting, and harvesting. The major agricultural NPS pollutants that result from these activities are sediment, nutrients, pathogens, pesticides, and salts.

Agricultural activities also can damage habitat and stream channels. Agricultural impacts on surface water and ground water can be minimized by properly managing activities that can cause NPS pollution. Numerous government programs are available to help people design and pay for management approaches to prevent and control NPS pollution. For example, over 40 percent of section 319 Clean Water Act grants were used to control agricultural NPS pollution. Also, several U.S. Department of Agriculture and state-funded programs provide cost-share, technical assistance, and economic incentives to implement NPS pollution management practices. Many people use their own resources to adopt technologies and practices to limit water quality impacts caused by agricultural activities.

Sedimentation occurs when wind or water runoff carries soil particles from an area, such as a farm field, and transports them to a water body, such as a stream or lake. Excessive sedimentation clouds the water, which reduces the amount of sunlight reaching aquatic plants; covers fish spawning areas and food supplies; and clogs the gills of fish. In addition, other pollutants like phosphorus, pathogens, and heavy metals are often attached to the soil particles and wind up in the water bodies with the sediment. Farmers can reduce erosion and sedimentation by 20 to 90 percent by applying management measures to control the volume and flow rate of runoff water, keep the soil in place, and reduce soil transport.

A. Filter Strips

Filter strips are land areas of either planted or indigenous vegetation, situated between a potential, pollutant-source area and a surface-water body that receives runoff. Runoff may carry sediment and organic matter, and plant nutrients and pesticides that are either bound to the sediment or dissolved in the water. A properly designed and operating filter strip provides water-quality protection by reducing the amount of sediment, organic matter, and some nutrients and pesticides, in the runoff at the edge of the field, and before the runoff enters the stream or ditch. Filter strips also provide localized erosion protection since the vegetation covers an area of soil that otherwise might have a high erosion potential.

Filter strips installed on cropland not only help remove pollutants from runoff, but also serve as habitat for wildlife, and provide an area for field turn rows and haymaking. In some instances, a filter strip could be used as pasture in a controlled-grazing, livestock management system, if livestock are kept fenced out of the stream. Additionally, filter strips may provide increased safety by moving machinery operations away from steep stream and ditch banks.

1. Processes

The purpose of a filter strip is to trap sediment, plant nutrients, organic matter and chemicals as runoff from cropland or urban areas passes through the vegetated area. Filter strips generally are more effective in trapping sediment, and therefore, sediment-bound nutrients and pesticides, than soluble nutrients and pesticides. Nutrients that bind to sediment include phosphorus and ammonium; soluble nutrients include nitrate. In addition, the filter will be much more effective when the runoff passes through the vegetation in the form of shallow, uniform flow compared to conditions where the flow is concentrated in small channels or gullies. Concentrated flow channels may actually allow the runoff to bypass the vegetation in the filter strip. Shallow, uniform flow provides for maximum contact time for the removal of pollutants by several physical processes, including deposition and infiltration. Biological and chemical processes may help break down and utilize nutrients and pesticides that are trapped in the filter.

2. Deposition

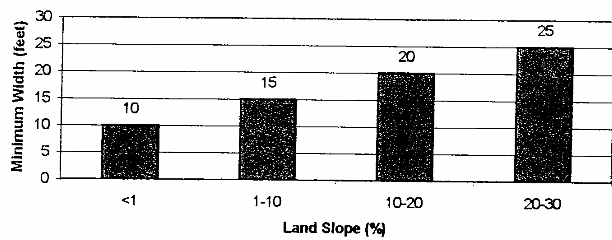
As runoff moves through the filter strip, sediment and other suspended materials may be filtered from the runoff, largely by deposition.. Deposition is the dominant process for the trapping of sediment, and most often sediment is deposited within the first few feet of the filter. As runoff enters the filter strip, the velocity of the runoff decreases, and sediment begins to settle out of the runoff. Large, sand- and silt-sized particles, and soil aggregates settle from the runoff within a relatively short distance into the filter. Small, finer particles, such as clay, may take a longer distance to settle out. Depending upon the quantity and velocity of the runoff, there may be little or no deposition of the fine, clay particles before the runoff exits the filter strip. Trapping sediment in the filter also helps to trap nutrients and pesticides that are sediment-bound.

In a filter strip, infiltration occurs as the runoff moves through the filter where it encounters vegetation, which helps decrease the flow velocity. Time is available for part of the runoff to infiltrate into the soil surface, and then percolate through the soil profile. The amount of infiltration and percolation depends upon soil characteristics. In addition, plant residues on the soil surface help increase infiltration, and plant roots in the soil profile may help improve soil structure, and increase soil aggregation and porosity, which help increase percolation. The filter strip actually helps reduce runoff by increasing infiltration, compared to possible conditions in the adjacent cropland. As runoff velocity is decreased, deposition and increased infiltration may occur. Also, some material suspended in the runoff may be filtered out as infiltration occurs.

Research indicates that filter strips are effective in the control of many agricultural and urban nonpoint source pollutants, but especially sediment. Field research on filter-strip width, using grass as the filter material, has been conducted in Indiana, Iowa, Maryland, and Virginia. The results indicate that filter strips are very effective in removing sediment from runoff, with the average reduction ranging from 56 to 95 percent, depending on soil characteristics, slope, rainfall and runoff conditions, and filter width.

The NRCS has developed general recommendations, based upon research, on the minimum filter-strip width for particular ranges of slope steepness (Figure VIII-1). However, filter-strip width also is affected by soil characteristics, and the shape and size of the land area draining into the filter. The values in Figure VIII-1 are recommended minimum widths, and could be adjusted upward if the sediment entering the filter has a high percentage of clay-sized particles, which take a longer distance to filter out compared to silt- and sand-sized particles. In addition, for slopes with a steepness of greater than 10 percent, there is increased potential for the runoff to be of sufficient volume and velocity to flow too fast through the filter, possibly laying over the vegetation and dramatically reducing its effectiveness.

Figure VIII-1
Recommended Filter Strip Widths



Much field research supports the use of filter widths in the range of 10 to 40 feet. However, ratios of the field drainage area to the filter area should be no greater than 50:1, and preferably in the range of 3:1 to 8:1. Based on a survey of more than 2,700 CRP sites in the United States, the ratio of drainage area to filter area averaged approximately 3:1.

3. Placement

As mentioned earlier, filter strips are usually installed along stream, lake, pond or sinkhole boundaries. A reason that some filter strips are not very effective is that the runoff entering the filter is in the form of concentrated flow. For maximum trapping efficiency, the runoff must reach the filter in the form of shallow, uniform flow. Therefore, the filter strip must be placed in a position that will intercept the runoff before it becomes concentrated in natural drainage channels within the field. In addition, filters should be constructed on the contour to help provide proper entrance conditions for shallow, uniform flow to enter the filter. Filter strips are not recommended for concentrated flow areas. Installing a terrace or grass waterway may be necessary to carry the concentrated flow through the field (contact SCS for assistance).

4. Vegetation

Plants selected for filter strips should have dense top-growth to provide good, uniform soil cover, and a fibrous root system for stability. In addition, the type of vegetation selected should be adapted to local soil and climatic conditions, and have good regrowth following dormancy and cutting. If the filter vegetation is to be used for hay or seed, other factors such as crop yield and feed quality need to be considered.

Grasses are more effective than broadleaf plants for erosion control since they form a dense sod, have a fibrous root system and provide a more complete ground cover. For filter-strip applications in Ohio, cool-season grasses are more desirable than warm-season grasses since they grow more vigorously in the spring and fall when little or no crop canopy is present and rainfall can be intense. Sod forming grasses are preferred over bunchgrasses since they provide more uniform ground cover. Bunchgrasses should only be used in combination with other plant species.

5. Installation

In general, the same considerations apply for the installation of a filter strip as for the establishment of a pasture or meadow. Once the type of vegetation is selected, soil fertility should be evaluated, and the seeding method selected. The amount of fertilizer and lime to be applied to the filter should be determined from the soil analysis taken from the cropland. Two types of tillage systems generally are used when seeding filter strips: conventional or no-till seeding. The recommended steps for conventional seeding of a filter strip are:

- Broadcast lime and fertilizer according to soil test recommendations.
- Incorporate lime and fertilizer with a disk or field cultivator.
- Prepare a firm seedbed (use of a cultipacker or cultimulcher is a good choice).
- Plant the seed shallow (1/4 inch deep) with a drill, cultipacker seeder or by broadcasting the seed; follow by cultipacking, making sure the seed is on a firm seed bed to obtain good seed-to-soil contact.

To seed and apply fertilizer properly using a conventional tillage method may require three to four tillage passes: fertilizer application, seedbed preparation, and planting. Using a no-till management system requires only a fertilizer spreading application and a no-till drill operation. With either management system, proper seed placement and good seed-to-soil contact are critical to successful forage establishment. Rapid filter-strip establishment is critical. During periods of dry weather, germination of the seed and early establishment of the vegetation in the filter may require irrigation.

6. Maintenance

Proper maintenance is required for maximum filter-strip effectiveness, just as for most other structural or non-structural best management practices, and normal crop production practices. Maintenance for grass and legume filters consists of several simple steps:

- Inspect the filter strip frequently, especially after intense rainfall events and runoff events of long duration. Small breaks in the sod and small erosion channels quickly become large problems.
- Minimize the development of erosion channels within the filter. Even small channels may allow much of the runoff from the field to bypass the filter. These areas should be repaired and reseeded immediately to help ensure proper flow of runoff through the filter.
- Reseed or interseed bare areas of the filter. Since it may be difficult to re-establish vegetation in an established filter strip, the use of mulch or sod can help to reduce some problems.
- Mow and remove hay as required (or as allowed by certain USDA programs) to maintain moderate vegetation height. Mowing two to three times per year may be necessary. The vegetation should not be mowed closer than 6 inches. If haying is not desirable (or allowed), more frequent mowing may be needed to prevent thatch buildup and smothering of vegetation. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July. Fall mowing of the filter no closer than 6 inches will provide adequate winter habitat for wildlife.
- Soil test periodically and apply soil amendments according to test results and recommendations.
- Control trees, brush, noxious weeds, and Canada thistle in the filter using either mechanical means or herbicides. Contact your county Extension office for recommendations on the proper chemicals to control weeds.

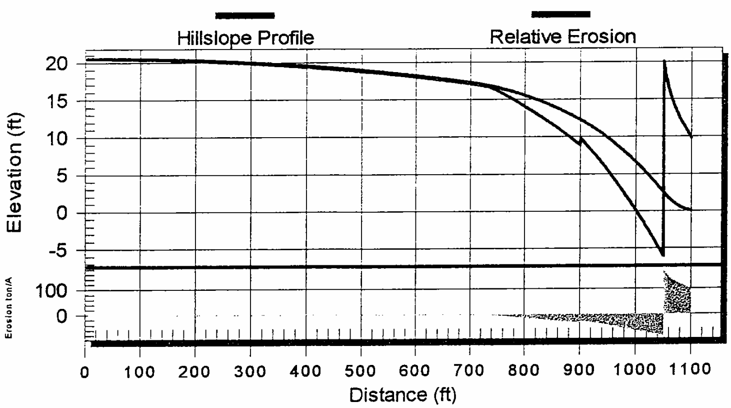
7. Effectiveness

Filter-strip effectiveness depends on soil characteristics, slope steepness, landscape shape, the ratio of the filter area to the area generating the runoff, filter width, and the type and quality of the vegetation in the filter. Overall, little information from field research is available about the long-term effectiveness of filter strips. However, computer simulations can provide some insight into how well filters may perform over time.

In the modeling effort presented earlier, the conditions modeled involved conventional cropland. The implementation of filter strips can be simulated by adjusting the management to change a strip of land at the field edge from cropland to permanent grass vegetation. In the following example, a 50-foot wide strip was modeled which caused the predicted average annual soil loss to change from 14.8 tons/acre to 11.6 tons/acre. Due to the trapping of sediment by deposition, the predicted reduction in average annual sediment yield decreased from 13.4 tons/acre to 5.3 tons/acre- a reduction of 60%.

Table VIII-1 Brush Creek Cropland Typical Erosion with Filter Strip					
Average Annual Precipitation 43.00 in Average Annual Runoff 2.00 in Average Annual Soil Loss 11.600 ton/A Average Annual Sediment Yield 5.300 ton/A					
Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
corn-spring chisel plow	900.0	4.39	900.0	0.00	0.0
corn-spring chisel plow	150.0	54.76	150.0	0.00	0.0
Grass	50.0	0.00	0.0	127.61	50.0
Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.90	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.30	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	54.76	150.0	0.00	0.0
IN\ HOLTON(SIL)	50.0	0.00	0.0	127.61	50.0

Figure VIII-2
Typical Cropland Erosion Profile with Filter Strips



B. Conservation Tillage

A filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that make an impact within the field. In the original modeling effort, crop production was simulated for the entire profile using spring tillage with a chisel plow. This included all soils mapped in the profile, including a 150-foot wide band mapped as Cincinnati silt loam with 6-12% slopes. The average of 9% was used in the model. Another simulation was modeled to include the 50-foot wide filter strip plus changing the 150-foot wide band from conventional tillage corn to no-til corn. The results of the simulation are shown as Table VIII-2 and Figure VIII-3 below. In this example, the predicted average annual soil loss changed from 11.6 tons/acre to 4.2 tons/acre. This decrease of nearly 64% is due largely to the decrease in sediment ***detachment***. The predicted reduction in average annual sediment yield decreased from 5.3 tons/acre to 2.4 tons/acre- an additional reduction of 22% of the original predicted average annual sediment yield of 13.4 tons/acre.

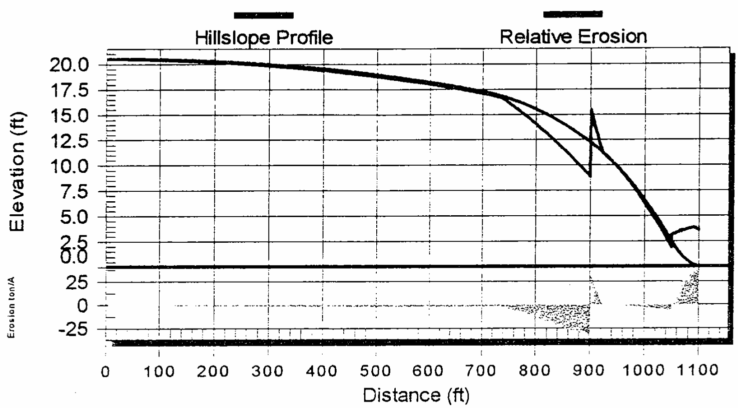
Table VIII-2
Brush Creek Cropland
Typical Erosion with No-Til & Filter Strip

Average Annual Precipitation 43.00 in
Average Annual Runoff 2.10 in
Average Annual Soil Loss 4.200 ton/A
Average Annual Sediment Yield 2.400 ton/A

Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
corn-spring chisel plow	900.0	4.39	900.0	0.00	0.0
corn-no till	150.0	2.60	127.5	15.52	22.5
Grass	50.0	0.00	0.0	26.59	50.0

Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.90	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.30	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	2.60	127.5	15.52	22.5
IN\ HOLTON(SIL)	50.0	0.00	0.0	26.59	50.0

Figure VIII-3
Typical Cropland Erosion Profile
with No-Til & Filter Strips



Filter strips can be a very useful BMP to help reduce the amount of sediment and nutrients leaving the field. Filter-strip effectiveness is dependent on soil characteristics, land size, slope and shape, quality of vegetative cover within the filter, and local land use and climatic factors. In addition, periodic filter-strip maintenance is required to maintain its effectiveness in improving and protecting water quality. It is important to note that a filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that make an impact ***within*** the field.

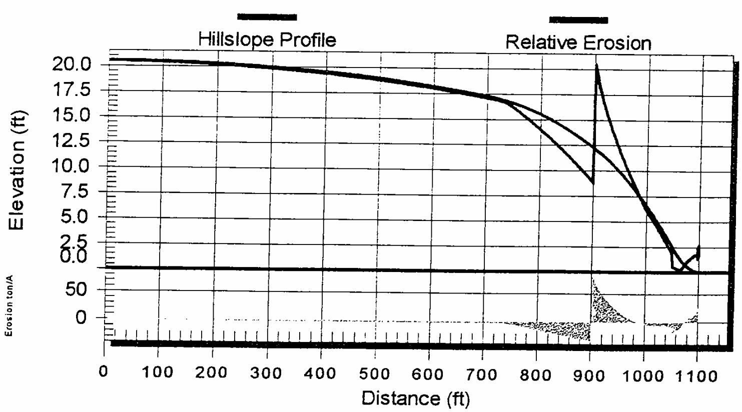
In previous modeling efforts, the effectiveness of filter strips was demonstrated to encourage deposition of sediment while the key emphasis on using no-til for crop production on slopes focuses on reducing the detachment of soil particles. It should be recognized that best management practices can complement each other and, in many situations, BMPs need to be combined to optimize their benefits.

C. Permanent Vegetation

In the final modeling exercise, the management adjustment involves vegetating the Cincinnati soil map unit with 6-12% slopes and the area down gradient with permanent grass vegetation. Instead of row crop production, the management regime could include hay harvesting and/or pasturing. Table VIII-3 and Figure VIII-4 summarizes the results of the modeling showing that the average annual soil loss is reduced from 14.8 tons/acre to 4.6 tons/acre. This represents a dramatic reduction in the volume of soil being detached- preventing excessive soil erosion from occurring. Average annual sediment yield drops from 13.4 tons/acre to 1.5 tons/acre.

Table VIII-3 Brush Creek Cropland Typical Erosion with Grass on Slope					
Average Annual Precipitation 43.00 in Average Annual Runoff 1.80 in Average Annual Soil Loss 4.600 ton/A Average Annual Sediment Yield 1.500 ton/A					
Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
corn-spring chisel plow	900.0	4.41	900.0	0.00	0.0
Grass	195.0	6.73	86.8	25.51	108.2
Grass	5.0	0.00	0.0	18.69	5.0
Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.90	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.39	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	4.97	63.0	29.27	87.0
IN\ HOLTON(SIL)	50.0	11.40	23.8	11.67	26.2

Figure VIII-4
Typical Cropland Erosion Profile with Grass on Slopes



2. Grazing Management BMPs

Overgrazing exposes soils, increases erosion, encourages invasion by undesirable plants, destroys fish habitat, and reduces the filtration of sediment necessary for building streambanks, wet meadows, and floodplains. To reduce the impacts of grazing on water quality, farmers and ranchers can adjust grazing intensity, keep livestock out of sensitive areas, and provide alternative sources of water and shade, and revegetated pastureland. Protect pasture and other grazing lands by implementing one or more of the following to protect sensitive areas (such as streambanks, wetlands, ponds, and riparian zones):

- Exclude livestock,
- Provide stream crossings or hardened/rocked watering access for drinking,
- Provide alternative drinking water locations,
- Locate salt and additional shade, if needed, away from sensitive areas,
- Use improved grazing management (e.g., herding) to reduce the physical disturbance and reduce direct loading of animal waste and sediment caused by livestock

The focus of grazing management is typically on the riparian zone, yet the control of erosion from pasture, and other grazing lands above the riparian zone is also encouraged. Application of this management will reduce the physical disturbance to sensitive areas and reduce the discharge of sediment, animal waste, nutrients, and chemicals to surface waters.

The key options to consider when developing a comprehensive grazing management approach at a particular location include the development of one or more of the following:

- Grazing management systems. These systems ensure proper grazing use through:
    - Grazing frequency (includes complete rest);
    - Livestock stocking rates;
    - Livestock distribution;
    - Timing (season of forage use) and duration of each rest and grazing period;
    - Livestock kind and class; and
    - Forage use allocation for livestock and wildlife.
- Proper water and salt supplement facilities.
- Livestock access control.
- Pasture rehabilitation.

For any grazing management system to work, it must be tailored to fit the needs of the vegetation, terrain, class or kind of livestock, and particular operation involved. Areas should be provided for livestock watering, salting, and shade that are located away from streambanks and riparian zones where necessary and practical. This will be accomplished by managing livestock grazing and providing facilities for water, salt, and shade as needed.

Special attention must be given to grazing management in riparian and wetland areas if management measure objectives are to be met. Riparian areas are defined as vegetated ecosystems along a waterbody through which energy, materials, and water pass. Riparian areas characteristically have a high water table and are subject to periodic flooding and influence from the adjacent waterbody.

The health of the riparian system, and thus the quality of water, is dependent on the use, management, and condition of the related uplands. Therefore, the proper management of riparian and wetland ecosystems will involve the correct management of livestock grazing and other land uses in the total watershed.

A. Pasture Management Practices

The practices set forth below have been found to be representative of the types of practices that can be applied successfully to protect sensitive areas such as the riparian corridor of Brush Creek. The numbers, where included, are Natural Resource Conservation Service practice numbers and definitions are provided for each management practice, where available. Also included are descriptions of the predicted effect each practice has on water quality.

1. Grazing Management System Practices

Appropriate grazing management systems ensure proper grazing use by adjusting grazing intensity and duration to reflect the availability of forage and feed designated for livestock uses, and by controlling animal movement through the operating unit of range or pasture. Proper grazing use will maintain enough live vegetation and litter cover to protect the soil from erosion; will achieve riparian and other resource objectives; and will maintain or improve the quality, quantity, and age distribution of desirable vegetation. Practices that accomplish this are:

a. Deferred grazing (352): Postponing grazing or resting grazing land for prescribed period.

In areas with bare ground or low percent ground cover, deferred grazing will reduce sediment yield because of increased ground cover, less ground surface disturbance, improved soil bulk density characteristics, and greater infiltration rates. Areas mechanically treated will have less sediment yield when deferred to encourage re-vegetation. Animal waste would not be available to the area during the time of deferred grazing and there would be less opportunity for adverse runoff effects on surface or aquifer water quality. As vegetative cover increases, the filtering processes are enhanced, thus trapping more silt and nutrients as well as snow if climatic conditions for snow exist. Increased plant cover results in a greater uptake and utilization of plant nutrients.

b. Planned grazing system (556): A practice in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years, and rest periods may be throughout the year or during the growing season of key plants.

Planned grazing systems normally reduce the system time livestock spend in each pasture. This increases quality and quantity of vegetation. As vegetation quality increases, fiber content in manure decreases which speeds manure decomposition and reduces pollution potential. Freeze-thaw, shrink-swell, and other natural soil mechanisms can reduce compacted layers during the absence of grazing animals. This increases infiltration, increases vegetative growth, slows runoff, and improves the nutrient and moisture filtering and trapping ability of the area.

Decreased runoff will reduce the rate of erosion and movement of sediment and dissolved and sediment-attached substances to downstream watercourses. No increase in ground water pollution hazard would be anticipated from the use of this practice.

c. Proper grazing use (528): Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.

Increased vegetation slows runoff and acts as a sediment filter for sediments and sediment attached substances, uses more nutrients, and reduces raindrop splash. Adverse chemical effects should not be anticipated from the use of this practice.

d. Proper woodland grazing (530): Grazing wooded areas at an intensity that will maintain adequate cover for soil protection and maintain or improve the quantity and quality of trees and forage vegetation.

This practice is applicable on wooded areas producing a significant amount of forage that can be harvested without damage to other values. In these areas there should be no detrimental effects on the quality of surface and ground water. Any time this practice is applied there must be a detailed management and grazing plan.

e. Pasture and hayland management (510): Proper treatment and use of pasture or hayland.

With the reduced runoff there will be less erosion, less sediment and substances transported to the surface waters. The increased infiltration increases the possibility of soluble substances leaching into the ground water.

2. Alternate Water Supply Practices

Providing water and salt supplement facilities away from streams will help keep livestock away from streambanks and riparian zones. The establishment of alternate water supplies for livestock is an essential component of this measure when problems related to the distribution of livestock occur in a grazing unit. In most western states, securing water rights may be necessary. Access to a developed or natural water supply that is protective of streambank and riparian zones can be provided by using the stream crossing (interim) technology to build a watering site. In some locations, artificial shade may be constructed to encourage use of upland sites for shading and loafing. Providing water can be accomplished through the following Natural Resource Conservation Service practices.

a. Pipeline (516): Pipeline installed for conveying water for livestock or for recreation.

Pipelines may decrease sediment, nutrient, organic, and bacteria pollution from livestock. Pipelines may afford the opportunity for alternative water sources other than streams and lakes, possibly keeping the animals away from the stream or impoundment. This will prevent bank destruction with resulting sedimentation, and will reduce animal waste deposition directly in the water. The reduction of concentrated livestock areas will reduce manure solids, nutrients, and bacteria that accompany surface runoff.

b. Pond (378): A water impoundment made by constructing a dam or an embankment or by excavation of a pit or dugout.

Ponds may trap nutrients and sediment that wash into the basin. This removes these substances from downstream. Chemical concentrations in the pond may be higher during the summer months. By reducing the amount of water that flows in the channel downstream, the frequency of flushing of the stream is reduced and there is a collection of substances held temporarily within the channel. A pond may cause more leachable substance to be carried into the ground water.

c. Trough or tank (614): A trough or tank, with needed devices for water control and waste water disposal, installed to provide drinking water for livestock.

By the installation of a trough or tank, livestock may be better distributed over the pasture, grazing can be better controlled, and surface runoff reduced, thus reducing erosion. By itself this practice will have only a minor effect on water quality; however when coupled with other conservation practices, the beneficial effects of the combined practices may be large. Each site and application should be evaluated on its own merits.

d. Well (642): A well constructed or improved to provide water for irrigation, livestock, wildlife, or recreation.

When water is obtained, if it has poor quality because of dissolved substances, its use in the surface environment or its discharge to downstream watercourses the surface water will be degraded. The location of the well must consider the natural water quality and the hazards of its use in the potential contamination of the environment. Hazard exists during well development and its operation and maintenance to prevent aquifer quality damage from the pollutants through the well itself by back flushing, or accident, or flow down the annular spacing between the well casing and the bore hole.

e. Spring development (574): Improving springs and seeps by excavating, cleaning, capping, or providing collection and storage facilities.

There will be negligible long-term water quality impacts with spring developments. Erosion and sedimentation may occur from any disturbed areas during and immediately after construction, but should be short-lived. These sediments will have minor amounts of adsorbed nutrients from soil organic matter.

3. Livestock Access Limitation Practices

It may be necessary to minimize livestock access to streambanks, ponds or lakeshores, and riparian zones to protect these areas from physical disturbance. This could also be accomplished by establishing special use pastures to manage livestock in areas of concentration. Practices include:

a. Fencing (382): Enclosing or dividing an area of land with a suitable permanent structure that acts as a barrier to livestock, big game, or people (does not include temporary fences).

Fencing is a practice that can be on the contour or up and down slope. Often a fence line has grass and some shrubs in it. When a fence is built across the slope it will slow down runoff, and cause deposition of coarser grained materials reducing the amount of sediment delivered downslope. Fencing may protect riparian areas that act as sediment traps and filters along water channels and impoundments.

Livestock have a tendency to walk along fences. The paths become bare channels which concentrate and accelerate runoff causing a greater amount of erosion within the path and where the path/channel outlets into another channel. This can deliver more sediment and associated pollutants to surface waters. Fencing can have the effect of concentrating livestock in small areas, causing a concentration of manure that may wash off into the stream, thus causing surface water pollution.

b. Livestock exclusion (472): Excluding livestock from an area not intended for grazing.

Livestock exclusion may improve water quality by preventing livestock from being in the water or walking down the banks, and by preventing manure deposition in the stream. The amount of sediment and manure may be reduced in the surface water. This practice prevents compaction of the soil by livestock and prevents losses of vegetation and undergrowth. This may maintain or increase evapotranspiration. Increased permeability may reduce erosion and lower sediment and substance transportation to the surface waters. Shading along streams and channels resulting from the application of this practice may reduce surface water temperature.

c. Stream crossing (interim): A stabilized area to provide access across a stream for livestock and farm machinery.

The purpose is to provide a controlled crossing or watering access point for livestock along with access for farm equipment, control bank and streambed erosion, reduce sediment and enhance water quality, and maintain or improve wildlife habitat.

4. Vegetative Stabilization Practices

It may be necessary to improve or reestablish the vegetative cover on range and pastures to reduce erosion rates. The following practices can be used to reestablish vegetation:

a. Pasture and hayland planting (512): Establishing and reestablishing long-term stands of adapted species of perennial, biannual, or reseeding forage plants. (Includes pasture and hayland renovation. Does not include grassed waterways or outlets or cropland.)

The long-term effect will be an increase in the quality of the surface water due to reduced erosion and sediment delivery. Increased infiltration and subsequent percolation may cause more soluble substances to be carried to ground water.

b. Critical area planting (342): Planting vegetation, such as trees, shrubs, vines, grasses, or legumes, on highly erodible or critically eroding areas. (Does not include tree planting mainly for wood products.)

This practice may reduce soil erosion and sediment delivery to surface waters. Plants may take up more of the nutrients in the soil, reducing the amount that can be washed into surface waters or leached into ground water.

During grading, seedbed preparation, seeding, and mulching, large quantities of sediment and associated chemicals may be washed into surface waters prior to plant establishment.

c. Brush (and weed) management (314): Managing and manipulating stands of brush (and weeds) on range, pasture, and recreation and wildlife areas by mechanical, chemical, or biological means or by prescribed burning. (Includes reducing excess brush (and weeds) to restore natural plant community balance and manipulating stands of undesirable plants through selective and patterned treatments to meet specific needs of the land and objectives of the land user.)

Improved vegetation quality and the decrease in runoff from the practice will reduce the amount of erosion and sediment yield. Improved vegetative cover acts as a filter strip to trap the movement of dissolved and sediment attached substances, such as nutrients and chemicals from entering downstream watercourses. Mechanical brush management may initially increase sediment yields because of soil disturbances and reduced vegetative cover. This is temporary until revegetation occurs.

B. Costs

Much of the cost associated with implementing grazing management practices is due to fencing installation, water development, and system maintenance. Costs vary according to region and type of practice. Generally, the more components or structures a practice requires, the more expensive it is. However, cost-share may be available from the USDA and other Federal agencies for these practices.

1. Grazing Facilities

Principal direct costs of providing grazing facilities vary from relatively low variable costs of dispersed salt blocks to higher capital and maintenance costs of supplementary water supply improvements. Improving the distribution of grazing pressure by herding or strategically locating grazing facilities to draw cattle away from streamside areas can result in improved utilization of existing forage.

The availability and feasibility of supplementary water development varies considerably between arid western areas and humid eastern areas, but costs for water development, including spring development and pipeline watering, are similar.

2. Livestock Exclusion

Principal direct costs of livestock exclusion are the capital and maintenance costs for fencing to restrict access to streamside areas or the cost of herders to achieve the same results. In addition, there may be an indirect cost of the forage that is removed from grazing by exclusion.

There is considerable difference between multistrand barbed wire, chiefly used for perimeter fencing and permanent stream exclusion and diversions, and single- or double-strand smoothwire electrified fencing used for stream exclusion and temporary divisions within permanent pastures. The latter may be all that is needed to accomplish most livestock exclusion in smaller, managed pastures in the East.

3. Improvement/Reestablishment

Principal direct costs of improving or reestablishing grazing land include the costs of seed, fertilizer, and herbicides needed to establish the new forage stand and the labor and machinery costs required for preparation, planting, cultivation, and weed control. An indirect cost may be the forage that is removed from grazing during the reestablishment work and rest for seeding establishment.

Since the exact combination of practices needed to implement the management measure depends on site-specific conditions that are highly variable, the overall cost of the measure is best estimated from similar combinations of practices applied under the Agricultural Conservation Program (ACP), Rural Clean Water Program (RCWP), and similar activities.

3. Silviculture BMPs

A. Managing Nonpoint Source Pollution from Forestry

Nearly 500 million acres of forested lands are managed for the production of timber in the United States. Although only a very small percentage of this land is harvested each year, forestry activities can cause significant water quality problems if improperly managed. The latest National Water Quality Inventory reports that forestry activities contribute to approximately 9 percent of the water quality problems in surveyed rivers and streams. Sources of NPS pollution associated with forestry activities include removal of streamside vegetation, road construction and use, timber harvesting, and mechanical preparation for the planting of trees. Road construction and road use are the primary sources of NPS pollution on forested lands, contributing up to 90 percent of the total sediment from forestry operations. Harvesting trees in the area beside a stream can affect water quality by reducing the streambank shading that regulates water temperature and by removing vegetation that stabilizes the streambanks. These changes can harm aquatic life by limiting sources of food, shade, and shelter.

Preharvest Planning: Opportunities to Prevent NPS Pollution

To limit water quality impacts caused by forestry, public and private forest managers have developed and followed site-specific forest management plans. Following properly designed preharvest plans can result in logging activities that are both profitable and highly protective of water quality. Such plans address the full range of forestry activities that can cause NPS pollution. They clearly identify the area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction, and maintenance, as well as for harvesting methods and forest regeneration.

Public meetings held under the authority of federal and state laws provide citizens with a good opportunity to review and comment on the development of forest management plans.

B. Factors Considered in the Preharvest Plan

Surveying the Site. Preactivity surveys can help identify areas that might need special protection or management during forestry operations. Sensitive landscapes usually have steep slopes, a greater potential for landslides, sensitive rock formations, high precipitation levels, or special ecological functions such as those provided by streamside vegetation. Forestry activities occurring in these areas have a high potential of affecting water quality.

Timing. Because most forestry activities disturb soil and contribute to erosion and runoff, timing operations carefully can significantly reduce their impact on water quality and aquatic life. Rainy seasons and fish migration and spawning seasons, for example, should be avoided when conducting forestry activities.

Establishing Streamside Management Areas (SMAs). Plans often restrict forestry activities in vegetated areas near streams (also known as buffer strips or riparian zones), thereby establishing special SMAs. The vegetation in a SMA is highly beneficial to water quality and aquatic habitat. Vegetation in the SMA stabilizes streambanks, reduces runoff and nutrient levels in runoff, and traps sediment generated from upslope activities before it reaches surface waters. SMA vegetation moderates water temperature by shading surface water and provides habitat for aquatic life. For example, large trees provide shade while alive and provide aquatic habitat after they die and fall into the stream as large woody debris.

Managing Road Construction, Layout, Use, and Maintenance. Good road location and design can greatly reduce the transport of sediment to water bodies. Whenever possible, road systems should be designed to minimize road length, road width, and the number of places where water bodies are crossed. Roads should also follow the natural contours of the land and be located away from steep gradients, landslide-prone areas, and areas with poor drainage. Proper road maintenance and closure of unneeded roads can help reduce NPS impacts from erosion over the long term.

Managing Timber Harvesting. Most detrimental effects of harvesting are related to the access and movement of vehicles and machinery, and the dragging and loading of trees or logs. These effects include soil disturbance, soil compaction, and direct disturbance of stream channels. Poor harvesting and transport techniques can increase sediment production by 10 to 20 times and disturb as much as 40 percent of the soil surface. In contrast, careful logging disturbs as little as 8 percent of the soil surface. Careful selection of equipment and methods for transporting logs from the harvest area to areas where logs are gathered can significantly reduce the amount of soil disturbed and delivered to water bodies. Stream channels should be protected from logging debris at all times during harvesting operations.

Managing Replanting. Forests can be regenerated from either seed or seedlings. Seeding usually requires that the soil surface be prepared before planting. Seedlings can be directly planted with machines after minimal soil preparation. In either case, the use of heavy machinery can result in significant soil disturbance if not performed carefully.

4. Homeowner BMPs

The well-known stories about environmental problems tend to focus on big, recognizable targets such as smoking industrial facilities, leaking toxic waste dumps, and messy oil spills. As a result, people often forget about water pollution caused by smaller nonpoint sources--especially pollution at the household level.

However, nonpoint source (NPS) pollution is the Nation's leading source of water quality degradation. Although individual homes might contribute only minor amounts of NPS pollution, the combined effect of an entire neighborhood can be serious. These include eutrophication, sedimentation, and contamination with unwanted pollutants.

To prevent and control NPS pollution, households can learn about the causes of such pollution and take the appropriate (and often money-saving) steps to limit runoff and make sure runoff stays clean.

A. Limit Paved Surfaces

Urban and suburban landscapes are covered by paved surfaces like sidewalks, parking lots, roads, and driveways. They prevent water from percolating down into the ground, cause runoff to accumulate, and funnel into storm drains at high speeds. When quickly flowing runoff empties into receiving waters, it can severely erode streambanks. Paved surfaces also transfer heat to runoff, thereby increasing the temperature of receiving waters. Native species of fish and other aquatic life cannot survive in these warmer waters.

To limit NPS pollution from paved surfaces households can substitute alternatives to areas traditionally covered by nonporous surfaces. Grasses and natural ground cover, for example, can

To limit NPS pollution from paved surfaces households can substitute alternatives to areas traditionally covered by nonporous surfaces. Grasses and natural ground cover, for example, can be attractive and practical substitutes for asphalt driveways, walkways, and patios. Some homes effectively incorporate a system of natural grasses, trees, and mulch to limit continuous impervious surface area. Wooden decks, gravel or brick paths, and rock gardens keep the natural ground cover intact and allow rainwater to slowly seep into the ground.

B. Landscape With Nature

Altering the natural contours of yards during landscaping and planting with non-native plants that need fertilizer and extra water can increase the potential for higher runoff volumes, increase erosion, and introduce chemicals into the path of runoff. In contrast, xeriscape landscaping provides households with a framework that can dramatically reduce the potential for NPS pollution.

Xeriscape incorporates many environmental factors into landscape design--soil type, use of native plants, practical turf areas, proper irrigation, mulches, and appropriate maintenance schedules. By using native plants that are well suited to a regions climate and pests, xeriscape drastically reduces the need for irrigation and chemical applications. Less irrigation results in less runoff, while less chemical application keeps runoff clean.

C. Proper Septic System Management

Malfunctioning or overflowing septic systems release bacteria and nutrients into the water cycle, contaminating nearby lakes, streams, and estuaries, and ground water. Septic systems must be built in the right place. Trampling ground above the system compacts soil and can cause the systems pipes to collapse. Also, septic systems should be located away from trees because tree roots can crack pipes or obstruct the flow of wastewater through drain lines. Proper septic system management is also important, and a system should be inspected and emptied every 3 to 5 years.

By maintaining water fixtures and by purchasing water-efficient showerheads, faucets, and toilets, households can limit wastewater levels, reducing the likelihood of septic system overflow. Most water conservation technologies provide long-term economic and environmental benefits.

D. Proper Chemical Use, Storage, and Disposal

Household cleaners, grease, oil, plastics, and some food or paper products should not be flushed down drains or washed down the street. Over time chemicals can corrode septic system pipes and might not be completely removed during the filtration process. Chemicals poured down the drain can also interfere with the chemical and biological breakdown of the wastes in the septic tank.

On household lawns and gardens, homeowners can try natural alternatives to chemical fertilizers and pesticides and apply no more than the recommended amounts. Natural predators like insects and bats, composting, and use of native plants can reduce or entirely negate the need for chemicals. Xeriscape can limit chemical applications to lawns and gardens.

If chemicals are needed around the home, they should be stored properly to prevent leaks and access by children. Most cities have designated sites for the proper disposal of used chemicals.

5. Septic System Alternatives

When site conditions are not suitable for the standard gravity-flow septic systems, whether from a shallow water table, poor percolation rates, or an inadequate soil layer, then there are several alternative methods for the treatment of effluent coming from a residence.

A. Mound System

The use of an elevated sand mound is one alternative to the conventional gravity flow system. For this method, you must have at least 24 inches of suitable soil and a slope of less than 11% to be able to install a sand mound system. It consists of a septic tank, a dosing chamber and the absorption mound. After the effluent reaches the dosing chamber from the septic tank, it is periodically pumped into the mound in an even fashion, therefore creating even distribution. By incorporating sand filtration and low pressure distribution a soil absorption system is created that produces treated sewage before the effluent even reaches the surrounding subsurface soil. The sand mound system can be costly, ranging from \$10,000- \$20,000, but the advantage comes from the fact that it needs only about 50% of the area that a gravity-flow system needs.

B. Low Pressure Dosing

A second alternative to the gravity system is the low pressure dosing technique that can be used when there is not enough space to install a standard system. This method uses a pump that evenly distributes the wastewater into trenches, therefore reducing the amount or trench area that would have been needed. The space needed using this system is about 40% less than with the gravity system.

C. Constructed Wetlands

Constructed wetlands are simple, effective wastewater treatment systems specifically designed and built to treat domestic, agricultural, industrial and mining wastewater. Constructed wetlands generally are used by small communities as an alternative to the more expensive conventional wastewater treatment plant, but they also provide an option for homeowners. A constructed wetland is designed and built to resemble a natural wetland. The sides and bottom of an 18-inch deep excavated area are covered with a synthetic or clay liner to prevent leaks. The size of the wetland depends on treatment needs and amount of water to be treated. The area is the filled with rock, gravel, sand, and soil. Aquatic vegetation is planted in order to provide habitat for the microorganisms that actually treat the wastewater. Wastewater from the home flows through the septic tank, where the solids are removed, and into the wetland where it is distributed evenly.

6. Wetland Management

Nonpoint source pollution has been identified at the Nation's leading source of surface water and ground water quality impairment. When properly managed, wetlands can help prevent NPS pollution from degrading water quality across the nation and at the local level within the Brush Creek watershed.

Properly managed wetlands can intercept runoff and transform and store NPS pollutants like sediment, nutrients, and certain heavy metal s without being degraded. In addition, wetlands vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff. Wetlands vegetation also regulates stream temperature by providing streamside shading.

Improper development or excessive pollutant loads can damage wetlands. The degraded wetlands can then no longer provide water quality benefits and the wetlands themselves can become significant sources of NPS pollution. Excessive amounts of decaying wetlands vegetation, for example, can increase biochemical oxygen demand, making habitat unsuitable for fish and other aquatic life. Degraded wetlands also release stored nutrients and other chemicals into surface water and ground water.

The Environmental Protection Agency recommends three management strategies to maintain the water quality benefits provided by wetlands:

- Preservation
- Restoration, and
- Construction of engineered systems that prevent runoff before it reaches receiving waters and wetlands.

A. Wetland Preservation

The first strategy protects the full range of wetlands functions by discouraging development activity. At the same time, this strategy encourages proper management of upstream watershed activities, such as agriculture, forestry, and residential development. Several programs administered by federal and state agencies protect wetlands by either controlling development activities that would affect wetlands or providing financial assistance to people who wish to protect them. In addition, nongovernmental groups that purchase wetlands for conservation purposes, such as The Nature Conservancy, The Trust for Public Land, and local land trusts, are playing an increasingly important role in protecting water quality.

B. Wetland Restoration

The second strategy promotes the restoration of degraded wetlands and riparian zones with NPS pollution control potential. Riparian zones are the vegetated ecosystems along Brush Creek watertables and are subject to periodic flooding and influence from the adjacent stream. They encompass wetlands and uplands, or some combination to these two landforms.

Restoration activities should recreate the full range of preexisting wetland functions. That means replanting degraded wetlands with native plant species and, depending on the location and degree of degradation, using structural devices to control water flows. Restoration projects factor in ecological principles, such as habitat diversity and the connections between different aquatic and riparian habitat types, which distinguish these kinds of projects from wetlands that are constructed for runoff pretreatment.

C. Designed Systems

The third strategy promotes the use of engineered vegetated treatment systems. These systems are especially effective at removing suspended solids and sediment from NPS pollution before the runoff reaches natural wetlands.

Constructed wetlands are typically designed complexes of water, plants, and animal life that simulate naturally occurring wetlands. Studies indicate the constructed wetlands can achieve sediment removal rates greater than 90 percent. Like filter strips, constructed wetlands offer an alternative to other systems that are more structural in design.

Healthy wetlands benefit fish, wildlife, and humans because they protect many natural resources, only one of which is clean water. Unfortunately, 95% of the wetlands in the Brush Creek watershed were lost in the last 200 years, and undisturbed wetlands still face threats from development. Wetlands protection must be considered to help prevent NPS pollution from further degrading the water quality of Brush Creek and to protect many other natural resources.

IX. RECOMMENDATIONS

The intent of this project is to describe conditions and trends in Brush Creek and its watershed and to identify potential water quality problems in subwatersheds. This assessment is to provide guidance for future management and land treatment project selection and to predict the impacts of those projects to Brush Creek. The purpose then of this diagnostic study then is to:

- Describe conditions and trends in Brush Creek Reservoir, Brush Creek, and the watershed.
- Identify potential nonpoint source water quality problems
- Propose specific direction for future work
- Predict and assess success factors for future work.

The recommendations for enhancing the water quality of Brush Creek center on:
- Reducing the generation of nonpoint sources of pollutants, particularly nutrients and sediment from the watershed.
- Reducing the delivery of nonpoint sources of pollutants to Brush Creek, the Brush Creek Reservoir, and the Vernon Fork Muscatatuck River.

The Brush Creek Reservoir assessment resulted in data that indicate the reservoir has become eutrophic. Based on the Indiana Trophic State Index, the reservoir scored 53 on a scale of 0 to 75 indicating eutrophication. Applying the Carlson Trophic State Index formulas netted similar results. Based on water transparency, the reservoir scored 66.2 and 67.3 based on Total Phosphorus. Chlorophyll-*a* measured in the reservoir resulted in a TSI of 44.2, which is in the mesotrophic range of that index however, chlorphyll-*a* sample filtering results may be skewed due to the use of the incorrect filters. That score then has discarded. The Carlson scale ranges from 20 to 80 with scores in the high 60s being eutrophic to hypereutrophic.

Total phosphorus loading was plotted with Vollenweider curves that predict allowable and excessive loading based on the mean depth. Total P loading was calculated to be 1.14 lb/ac/yr (0.128 $g/m^2/yr$), which is in the excessive range of the chart based on the mean depth of the reservoir.

Samples collected from Brush Creek proper and tributaries confirm watershed conditions that accelerate the eutrophication process. Storm water samples collected from ***all*** stream sampling locations had total P levels that were at least double the targeted level. Dissolved phosphorus levels were also elevated.

Samples collected from the hypolimnion of the reservoir however, suggested that the reservoir suffers from internal P loading as well. Therefore, the goal of management for this reservoir is not necessarily to eliminate productivity, but to prevent an unacceptable acceleration in the aging process to the point that desired values and uses of the reservoir are impaired.

This study has concluded that Brush Creek's lowered water quality may be a result of agricultural practices and overall lack of watershed management. Certain watershed conditions and prevailing practices warrant attention and further study by those wanting to preserve the habitat quality of

Brush Creek and retard the eutrophication of Brush Creek Reservoir. Internal P loading will continue to be a contributing factor that is beyond the control of future watershed practices however watershed BMPs will determine future preservation or degradation of the reservoir.

The loss of 95% of the natural wetlands combined with intensive agricultural production are circumstances that support the presence of elevated nutrients and sediment in the runoff from the watershed- especially in the upper regions found in Ripley County. Even though some conservation tillage methods have likely helped to alleviate this condition, the silt and topsoil washed into the stream and reservoir during heavy rainfall events is still coating rocks and filling the pools and having a negative impact on the reservoir. Soil conservation efforts including conservation tillage and addition of filter strips should be intensified to prevent soil transport to the stream and reservoir. These grass buffers would also filter nutrients before they reach the waterways.

Third, access of cattle to the stream's ecosystem should be discouraged. The monitoring results at sample location #9 are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek. Also, the E. coli counts increased as the percentage of pasture increased within the subwatersheds. There is an apparent trend as the E.coli count was lowest at point 10, where percent pasture was the lowest. At sample points 4, 5, and 6, where pasture constitutes 14-15% of the landuse, E. coli counts were the highest observed. These counts do not necessarily indicate cattle are directly accessing the streams however there does appear to be a correlation between the pasture landuse percentage and the coliform counts.

Wildlife habitat in the form of forbs, shrubs and trees benefit wildlife and are also attractive- often adding to the value of real estate. Well managed wildlife habitats can save energy, protect soil and improve water and air quality. Trees and other plants hold soils in place during rain and wind. Vegetation helps keep sediment and contaminants from entering water bodies. In the right places, wildlife habitat can offer privacy and reduce dust and noise from road traffic. Plants also improve air quality by removing carbon dioxide from the air and replenishing it with oxygen.

Finally, wetland preservation, wetland restoration, and wetland construction should be pursued throughout the watershed- in that order. The development of additional wetlands to capture and treat agricultural fertilizer runoff deserves consideration in future studies.

1. Conservation Tillage

Crop-residue management through conservation tillage is one of the best and most cost-effective ways to reduce soil erosion. Conservation tillage and residue management can reduce machinery expenses and save soil, labor, fuel and money. Crop residues uniformly distributed over the soil surface will significantly reduce soil losses over an entire field.

Two mechanisms are involved in soil erosion: soil detachment and soil transport. Most soil detachment is caused by raindrop impact, a major factor in sheet erosion. Sheet erosion can go almost undetected for years, often causing great losses in productivity before the landowner becomes concerned.

Some soil detachment is caused by flowing water, especially where water concentrates to cause gullies. Gullies created by flowing water may be either ephemeral or permanent gullies. Short-lived gullies may be filled in by heavy tillage operations but tend to reform annually in the same location.

Residue (and crop canopy) can reduce soil detachment by absorbing the impact of falling raindrops. Also, residue may form small dams which retard runoff and create puddles of water that can absorb raindrop energy, thus reducing both detachment and transport of soil particles.

Sufficient amounts of crop residue left on the soil surface can almost eliminate erosion on many fields and greatly reduce erosion on other fields. In areas of concentrated water flow, such as natural or designed drainage ways, crop residues alone generally are not enough to control erosion. Such areas may require permanent grass seedings and/or some structural measures such as diversions or terraces (especially to control gully erosion). On long slopes, detached crop residues may be floated away by the higher water velocities attained in sheet flow. Once removed, erosion due to detachment and transport will accelerate. Terraces and diversions, in combination with crop residues, may be needed to control sheet erosion.

Conservation tillage is defined to be any tillage/planting system which leaves at least 30 percent of the field surface covered with crop residue after planting has been completed. Residue management (through conservation tillage) for erosion control can be enhanced by:

- Selection of crops that produce large amounts of residue (such as corn and grain sorghum) and/or a high degree of soil cover per pound of residue (such as wheat).
- Selection of a crop sequence that frequently renews the residue cover (e.g., double-cropping or use of winter cover crops).
- Use of crops that provide long-lasting residue (i.e., crops with a high carbon-to-nitrogen ratio, e.g., wheat).
- Uniform spreading of the residue by the combine (combines with headers 20 feet, or wider, may require special chaff spreaders).
- Minimizing the loss of cover due to tillage operations.
- Use of irrigation to produce high-yielding crops, especially in drought years.

Minor benefits from conservation tillage may result from less tillage leaving the soil surface rougher to retard runoff and increase infiltration. Random roughness may result in shallow puddles, which absorb some of the impact of falling raindrops (water deeper than the raindrop diameter can absorb a considerable portion of the raindrop energy). Contoured furrows, especially from twisted chisel points or ridge planting, may temporarily impound water during heavy rains. This impounded water can absorb raindrop impact and increase infiltration (especially if compared to furrows up and downhill).

However, little credit for soil-loss reduction is given to these factors, since these benefits may be temporary and usually are eliminated by future rains and/or additional tillage. Residue cover therefore is credited as the major factor for reducing soil loss with conservation tillage.

Conservation tillage systems offer numerous benefits that intensive or conventional tillage simply can't match:

- Reduces labor, saves time. As little as one trip for planting compared to two or more tillage operations means fewer hours on a tractor and fewer labor hours to pay ... or more acres to farm. For instance, on 500 acres the time savings can be as much as 225 hours per year. That's almost four 60-hour weeks.

- Saves fuel. Save an average 3.5 gallons an acre or 1,750 gallons on a 500-acre farm.
- Reduces machinery wear. Fewer trips save an estimated $5 per acre on machinery wear and maintenance costs—a $2,500 savings on a 500-acre farm.

- Improves soil tilth. A continuous no-till system increases soil particle aggregation (small soil clumps) making it easier for plants to establish roots. Improved soil tilth also can minimize compaction. Of course, compaction is also reduced by reducing trips across the field.

- Increases organic matter.The latest research shows the more soil is tilled, the more carbon is released to the air and the less carbon is available to build organic matter for future crops. In fact, carbon accounts for about half of organic matter.

- Traps soil moisture to improve water availability. Keeping crop residue on the surface traps water in the soil by providing shade. The shade reduces water evaporation. In addition, residue acts as tiny dams slowing runoff and increasing the opportunity for water to soak into the soil. Another way infiltration increases is by the channels (macropores) created by earthworms and old plant roots. In fact, continuous no-till can result in as much as two additional inches of water available to plants in late summer.

- Reduces soil erosion. Crop residues on the soil surface reduce erosion by water and wind. Depending on the amount of residues present, soil erosion can be reduced by up to 90% compared to an unprotected, intensively tilled field.

- Improves water quality .Crop residue helps hold soil along with associated nutrients (particularly phosphorous) and pesticides on the field to reduce runoff into surface water. In fact, residue can cut herbicide runoff rates in half. Additionally, microbes that live in carbon-rich soils quickly degrade pesticides and utilize nutrients to protect groundwater quality.

- Increases wildlife. Crop residues provide shelter and food for wildlife, such as game birds and small animals.

- Improves air quality. Crop residue left on the surface improves air quality because it reduces wind erosion, thus it reduces the amount of dust in the air; reduces fossil fuel emissions from tractors by making fewer trips across the field; and reduces the release of carbon dioxide into the atmosphere by tying up more carbon in organic matter.

2. Filter Strips

As an edge-of-the-field best management practice, filter strips are regarded as a reactive measure to soil erosion as compared to a proactive measure. Filter strips are a tool for effecting soil deposition and could be categorized a "second best" management practice to measures that prevent soil detachment in the first place. Nevertheless, filter strips are recommended as first priority to prevent further degradation of water quality and sedimentation to the Brush Creek Reservoir.

Filter strips apply as a practice to treat sheet overland flow- primarily on cropland but also can be effective on pasture at the lower edge of fields. Filter strips are also appropriate to install above conservation practices such as terraces or diversions. They area especially recommended, for purposes of this study, adjacent to Brush Creek and its tributaries.

The effectiveness of filter strips has been summarized. In general, vegetative-filter strips are:

- Effective in reducing the amount of sediment and nutrients in runoff from cropland.
- More effective in removing sediment than nutrients (research results on reducing nutrient losses are highly variable compared to sediment).
- More effective for runoff in the form of shallow, uniform flow compared to concentrated flow conditions.
- More effective when vegetation in the filter is of high quality.
- Most effective in removing sediment in the first 8 to 12 feet of the strip (filter width must be longer to effectively trap fine clay-sized particles compared to silt- and sand-sized particles).
- Most effective when the filter-strips width, location, and vegetation are matched to the soil, slope and drainage conditions at the specific site.
- Less effective as the cropland area drained through the vegetated area is increased.
- Less effective when the depth of flowing water moving through the filter is greater than the height of the vegetation in the filter (vegetation tends to lay over, which may help protect the filter-strip area from erosion, but the filter's trapping efficiency decreases dramatically).
- Less effective as sediment and nutrients build up in the vegetation.
- Less effective in trapping sediment and nutrients if runoff events occur very frequently (little or no rest or growth period between events).
- Less effective in some agricultural areas where flow from surface and subsurface drainage improvements bypasses the filter.
- Less effective when the filter strip is grazed during establishment or during wet soil conditions.
- Less effective when the filter strip is not maintained.

Filter strips can be a very useful BMP to help reduce the amount of sediment and nutrients leaving the field. Filter strip effectiveness is dependent on soil characteristics, land size, slope and shape, quality of vegetative cover within the filter, and local land use and climatic factors. In addition, periodic filter-strip maintenance is required to maintain its effectiveness in improving and protecting water quality. A filter strip is an edge-of-the-field best management practice, and should be used in conjunction with other best management practices that make an impact within the field. It should be recognized that best management practices can complement each other and, in many situations, BMPs need to be combined to optimize their benefits.

In general, the same considerations apply for the installation of a filter strip as for the establishment of a pasture or meadow. However, land grading or other soil surface preparations may be necessary to ensure that the filter will function properly, and that runoff will enter the filter in the form of shallow, uniform flow. A filter strip designed by a technical agency (i.e., NRCS or IDNR) should show the final filter grade and dimensions on the plan or staked in the field.
Once the type of vegetation is selected, soil fertility should be evaluated, and the seeding method selected. The amount of fertilizer and lime to be applied to the filter should be determined from the soil analysis taken from the cropland.

Two types of tillage systems generally are used when seeding filter strips: conventional or no-till seeding. The recommended steps for conventional seeding of a filter strip are:

- Broadcast lime and fertilizer according to soil test recommendations.
- Incorporate lime and fertilizer with a disk or field cultivator.
- Prepare a firm seedbed (use of a cultipacker or cultimulcher is a good choice).
- Plant the seed shallow (1/4 inch deep) with a drill, cultipacker seeder or by broadcasting the seed; follow by cultipacking, making sure the seed is on a firm seed bed to obtain good seed-to-soil contact.

To seed and apply fertilizer properly using a conventional tillage method may require three to four tillage passes: fertilizer application, seedbed preparation, and planting. Using a no-till management system requires only a fertilizer spreading application and a no-till drill operation. With either management system, proper seed placement and good seed-to-soil contact are critical to successful forage establishment.

Rapid filter-strip establishment is critical. During periods of dry weather, germination of the seed and early establishment of the vegetation in the filter may require irrigation.

3. Livestock Exclusion

Within the Brush Creek watershed, beef cattle herds are not the primary enterprises of the farms. The Indiana Agricultural Statistics 2001 Beef Cow Inventory report states that Jennings County ranks 24th in the State with 3,100 beef cows. Ripley County, with 5,000 beef cows, ranks 9th, however those are believed to be more concentrated to the southeast part of the county based on the distribution of prime farmland across the county.

Samples collected from location #9 had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, slightly elevated temperature and conductivity readings, and elevated levels of Ammonia N, TKN, Organic N, Total N, Total P, and turbidity.

These results are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek. Access of cattle to the stream's ecosystem should be discouraged. Based on the observations of the apparent management regimes of cattle operations along the stream ecosystems, those subwatersheds with the highest concentrations of cattle operations should be focused on.

Any practice that reduces the amount of time cattle spend in a stream, and hence reduces the manure loading, will decrease the potential for adverse affects of water pollution from grazing livestock. It has been shown that providing a water trough as an alternative drinking source may reduce the instream fecal deposition during the winter by as much as 90 percent (Moore et al. 1993). In addition, Clawson (1993) found that summer stream use dropped from 4.7 min/cow/day to 0.9 min/cow/day and bottom land use dropped from 8.3 to 3.9 min/cow/day when a water trough was provided as an alternative water source. This indicates that reductions of creek use by cattle can be achieved without fencing them out of the creek, however exclusion by fencing is preferred.

4. Wildlife Habitat

A century ago, numerous farm fields were small by today's standards. Brushy fencerows, idle crop fields, and unimproved pastures were common and farming provided an abundance of well-distributed wildlife cover. In the past half century, corn and soybean acreage increased while small grains and hay have decreased. In addition, woodlands are lost to agriculture, industrial, and residential development. Wildlife habitat improvement can greatly increase the abundance and variety of wild populations.

Many species of wildlife depend on "edge" conditions that can be provided by:

- Fencerow & Field Edge Plantings
- Tree Plantations
- Woods Edge Management
- "Odd Areas"

5. Wetlands

Based on an analysis of the hydric soils mapped in the soil surveys of Jennings and Ripley counties and located in the Brush Creek watershed, there were approximately 2,795 acres of wetlands in the Brush Creek watershed 200 years ago. Combining the information from the NWI and the assessment of hydric soils mapped in the soil surveys yields the following summary:

- Total land area 9,240 acres

- Estimated wetlands circa 1780s — 2,795 acres
- Percent of surface area in wetlands circa 1780s — 30.2%
- Existing wetlands — 124 acres
- Percent of surface area in wetlands today — 1.3%
- Percent of wetlands lost — 95%

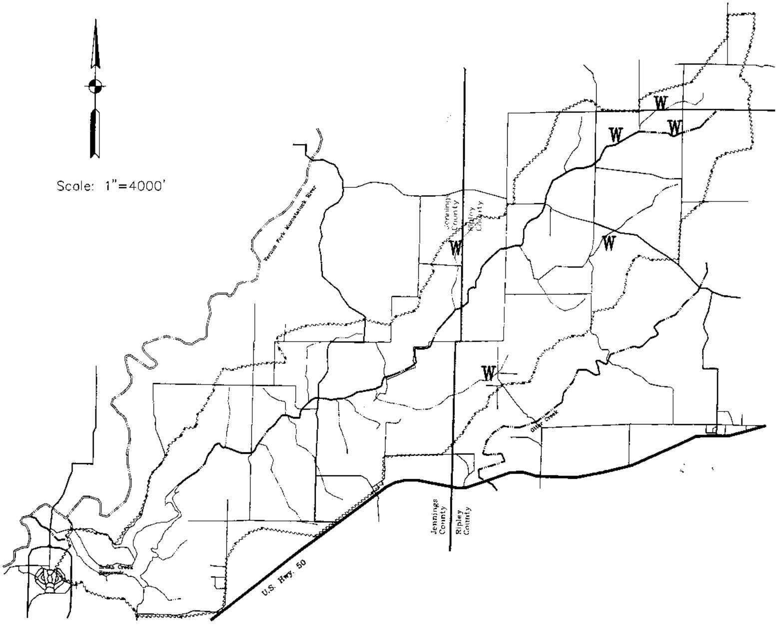
This assessment suggests that wetland loss within the Brush Creek watershed is somewhat greater than the loss experienced Statewide during the same time period. The majority of this loss is attributed to artificial drainage and conversion to cropland.

When properly managed, wetlands can help prevent non point source pollution from further degradation of the water quality within the Brush Creek Reservoir and Brush Creek itself. Figure IX-1 presents six possible locations for consideration as wetland sites. These sites are identified based on their proximity to intensive agricultural production with the criteria set to intercept runoff from these areas, to trap sediments in the runoff, and to assimilate nutrients associated with the runoff itself and the sediment deposited.

Properly managed wetlands can intercept runoff and transform and store non point source pollutants like sediment, nutrients, and certain heavy metal s without being degraded. In addition, wetlands vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff. Wetlands vegetation also regulates stream temperature by providing streamside shading.

The sponsoring SWCDs are encouraged to apply for funds for the creation of additional treatment wetlands in areas, which currently do not benefit from an interface wetland. At the same time, the SWCDs may consider the restoration of particular wetlands within the watershed. Efforts should be directed toward ensuring that existing Federal laws protecting wetland areas are enforced within the Brush Creek watershed.

The recommendations, for the most part, involve private land where lack of incentive and financial ability on the landowner's part may limit implementation. Cost-sharing assistance may be available through the Lake and River Enhancement Program and other State or Federal programs. Typically, programs offer technical and financial assistance for design and construction projects and watershed land treatment projects.



W– Potential Wetland Sites

Figure IX–1

Brush Creek Watershed Project

Potential Wetlands Location Map

DONAN ENGINEERING CO., INC.
4342 North US 231
Jasper, IN 47546
(812) 482-5611

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XI. APPENDIX

XI. 1 IDNR- DIVISION OF NATURE PRESERVES RESPONSE LETTER

DNR Indiana Department of Natural Resources

Frank O'Bannon, Governor
Larry D. Macklin, Director
Division of Nature Preserves
402 W. Washington Street, Rm. W267
Indianapolis, IN 46204-2739

October 18, 2001

Mr. Edward J. Knust
Donan Engineering Company, Inc.
4342 North US 231
Jasper, IN 47546

Dear Mr. Knust:

I am responding to your request for information on the endangered, threatened, or rare (ETR) species, high quality natural communities, and natural areas documented from the Brush Creek Watershed, Jennings and Ripley Counties, Indiana. The Indiana Natural Heritage Data Center has been checked and there are no ETR species and significant areas documented from the project area.

The information I am providing does not preclude the requirement for further consultation with the U.S. Fish and Wildlife Service as required under Section 7 of the Endangered Species Act of 1973. You should contact the Service at their Bloomington, Indiana office.

U.S. Fish and Wildlife Service
620 South Walker St.
Bloomington, Indiana 47403-2121
(812)334-4261

At some point, you may need to contact the Department of Natural Resources' Environmental Review Coordinator so that other divisions within the department have the opportunity to review your proposal. For more information, please contact:

Larry Macklin, Director
Department of Natural Resources
attn: Stephen H. Jose
Environmental Coordinator
Division of Fish and Wildlife
402 W. Washington Street, Room W273
Indianapolis, IN 46204
(317)232-4080

Please note that the Indiana Natural Heritage Data Center relies on the observations of many individuals for our data. In most cases, the information is not the result of comprehensive field surveys conducted at particular sites. Therefore, our statement that there are no documented significant natural features at a site should not be interpreted to mean that the site does not support special plants or animals.

Due to the dynamic nature and sensitivity of the data, this information should not be used for any project other than that for which it was originally intended. It may be necessary for you to request updated material from us in order to base your planning decisions on the most current information.

Thank you for contacting the Indiana Natural Heritage Data Center. You may reach me at (317)232-4052 if you have any questions or need additional information.

Sincerely,

Ronald P. Hellmich

Ronald P. Hellmich
Indiana Natural Heritage Data Center

XI. 2 IDNR DIVISION OF HISTORIC PRESERVATION AND ARCHAEOLOGY RESPONSE LETTER

Indiana Department of Natural Resources

Frank O'Bannon, Governor
Larry D. Macklin, Director

Division of Historic Preservation
and Archaeology
402 W Washington Street, W274
Indianapolis IN 46204-2748
PH 317/232-1646
FAX 317/232-0693
dhpa@dnr.state.in.us

November 19, 2001

Edward J. Knust
Senior Environmental Project Manager
Donan Engineering Company, Inc.
4342 North US 231
Jasper, Indiana 47546

Dear Mr. Knust:

We have reviewed the request for known historical or archaeological information for the diagnostic study of the Brush Creek Reservoir and watershed in Jennings and Ripley Counties, Indiana.

We recommend that you refer to both the Jennings and Ripley County Interim Reports, Indiana Survey of Historic Sites and Structures in order to provide yourselves with a survey of historic buildings and structures within and adjacent to your project area. A copy of the publication may be purchased through the Historic Landmarks Foundation of Indiana at (317) 639-4534. Our office also recommends that you refer to Historic Indiana, a publication that provides a list all those properties listed in the National Register of Historic Places within Indiana. The publication is available for reference at many local libraries. You may also get a list of properties listed in the National Register of Historic Places through the Internet by accessing the Indiana Department of Natural Resources Home page. The address is http://www.ai.org/dnr. Once in the IDNR Home page, go to the Historic Preservation Page. From there, you may click on an icon, which will link you immediately to the National Park Service database, where a comprehensive list of properties is available. For further information, refer to the enclosed document entitled, "Useful Resources for Section 106 Reviews."

However, without more detailed information, we are unable to comment on whether or not there are properties that meet the criteria to be considered eligible for inclusion in the National Register. If after further investigation a formal review of this project is necessary as a result of state funding, federal funding, permitting, or licensing, our office will assist the state or federal agency responsible for administering the project in evaluating the historical significance of the properties within the area of potential effect. Enclosed is a document entitled, "Summary of the Key Steps for carrying out the Section 106 Review Process in Indiana." Please refer to this document for an explanation of the federal review process. The enclosed document entitled, "Information needed to begin the Section 106 Review Process" will provide you with a list of information that must be submitted to our office if a formal review is required (e.g., clear photographs, the known or approximate dates of construction, and any available historical documentation).

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With respect to the archaeological aspects of this project, there are no known archaeological sites listed in the Indiana Register of Historic Sites and Structures or the National Register of Historic Places within or immediately adjacent to the project area. There are three recorded archaeological sites within the project area. However, the majority, if not all, of theproject area has not been assessed by a professional archaeologist. Based upon our knowledge of the region, the proposed project area is physiographically suitable to contain archaeological resources. If you have any further questions regarding the archaeological aspects of this project, please call Dr. Rick Jones or Bill Mangold at 317-232-1646.

Very truly yours,

Larry D. Macklin
State Historic Preservation Officer

LDM:BMN:WLM:wlm

Enclosures

XI. 3 STORM SAMPLING ANALYTICAL REPORTS

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job Number: 01.02946

Enclosed are the Analytical Results for the following samples submitted to TestAmerica, Inc. Indianapolis Division for analysis:

Project Description: BRUSH CREEK

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
294980	1	06/06/2001		06/07/2001
294981	2	06/06/2001		06/07/2001
294982	3	06/06/2001		06/07/2001
294983	4	06/06/2001		06/07/2001
294984	5	06/06/2001		06/07/2001
294985	6	06/06/2001		06/07/2001
294986	7	06/06/2001		06/07/2001
294987	8	06/06/2001		06/07/2001
294988	9	06/06/2001		06/07/2001
294989	10	06/06/2001		06/07/2001

TestAmerica, Inc. certifies that the analytical results contained herein apply only to the specific samples analyzed.

TestAmerica Incorporated-Indianapolis Division is in compliance with the National Environmental Laboratory Accreditation Program (NELAP) Standards.

Reproduction of this analytical report is permitted only in its entirety.

Sarah Thomas

Project Representative

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02946

Date Received: 06/07/2001
Job Description: BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294980 1			06/06/2001				
Nitrogen, Ammonia Dist.	0.16		mg/L	sld	06/21/2001 14:41	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.1		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	0.26	h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.02
Nitrogen, Nitrite	<0.02	h	mg/L	dsp	06/11/2001	EPA 353.2	<0.02
Phosphorus, Total	0.053		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.050		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	3.29		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			sld	06/21/2001 13:55		Complete
294981 2			06/06/2001				
Nitrogen, Ammonia Dist.	0.16		mg/L	sld	06/21/2001 14:41	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.1		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	0.44	h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.02
Nitrogen, Nitrite	0.032	h	mg/L	dsp	06/11/2001	EPA 353.2	<0.02
Phosphorus, Total	0.066		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.050		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	10.5		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			sld	06/21/2001 13:55		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02946

Date Received: 06/07/2001
Job Description: BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294982 3			06/06/2001				
Nitrogen, Ammonia Dist.	0.18		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.82		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	0.29	h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.02
Nitrogen, Nitrite	0.031	h	mg/L	dsp	06/11/2001	EPA 353.2	<0.02
Phosphorus, Total	<0.050		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.050		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	4.18		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294983 4			06/06/2001				
Nitrogen, Ammonia Dist.	0.31		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.6		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	3.4	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.43		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.088		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	177		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02946

Date Received: 06/07/2001
Job Description: BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294984 5			06/06/2001				
Nitrogen, Ammonia Dist.	0.46		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.4		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	4.3	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.35		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.12		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	160		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294985 6			06/06/2001				
Nitrogen, Ammonia Dist.	0.30		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.1		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	3.8	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.37		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.099		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	103		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02946

Date Received: 06/07/2001
Job Description: BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294986 7			06/06/2001				
Nitrogen, Ammonia Dist.	0.27		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.9		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	1.9	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.33		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.14		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	38.8		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294987 8			06/06/2001				
Nitrogen, Ammonia Dist.	0.30		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.3		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	2.4	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.31		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.13		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	44.7		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete

6964 Hillsdale Court / Indianapolis, IN 46250 / 317-842-4261 / Fax: 317-842-4286 / 800-485-0204

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

06/21/2001

Job No.: 01.02946

Date Received: 06/07/2001
Job Description: BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
294988 9			06/06/2001				
Nitrogen, Ammonia Dist.	0.22		mg/L	cdk	06/19/2001 12:21	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.3		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	1.9	h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.02
Nitrogen, Nitrite	0.042	h	mg/L	dsp	06/11/2001	EPA 353.2	<0.02
Phosphorus, Total	0.27		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.11		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	48.1		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/18/2001 14:35		Complete
294989 10			06/06/2001				
Nitrogen, Ammonia Dist.	0.32		mg/L	dsp	06/19/2001 17:29	EPA 350.1	<0.10
Nitrogen, Kjeldahl	2.5		mg/L	cdk	06/15/2001 15:42	EPA 351.2	<0.30
Nitrogen, Nitrate	5.1	d1x10,h	mg/L	dsp	06/11/2001 15:32	EPA 353.2	<0.20
Nitrogen, Nitrite	<0.20	d2x10,h	mg/L	dsp	06/11/2001	EPA 353.2	<0.20
Phosphorus, Total	0.31		mg/L	tpd	06/11/2001 12:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.12		mg/L	tpd	06/13/2001 10:30	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	06/11/2001 12:00		Complete
Turbidity	51.0		NTU	jss	06/07/2001 12:15	EPA 180.1	<1.
Digestion, TKN	Complete			sld	06/14/2001 08:50		Complete
Distillation, Ammonia	Complete			rlm	06/19/2001 14:00		Complete

TestAmerica
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KEY TO ABBREVIATIONS

<	Less than; when appearing in the result column, indicates analyte not detected at or above the Reporting Limit.
%	Percent; To convert ppm to %, divide result by 10,000. To convert % to ppm, multiply the result by 10,000.
*	Indicates the Reporting Limit is elevated due to insufficient sample volume.
mg/L	Part per million; Concentration in units of milligrams of analyte per Liter of aqueous sample.
ug/L	Part per billion; Concentration in units of micrograms of analyte per Liter of aqueous sample.
mg/kg	Part per million; Concentration in units of milligrams of analyte per kilogram of non-aqueous sample.
ug/kg	Part per billion; Concentration in units of micrograms of analyte per kilogram of non-aqueous sample.
a	Indicates the sample concentration was quantitated using a diesel fuel standard.
b	Indicates the analyte of interest was also found in the method blank.
c	Sample resembles unknown Hydrocarbon.
dw	When indicated, the result is reported on a dry weight basis. The contribution of the moisture content in the sample has been subtracted when calculating the concentration.
d1	Indicates the analyte has elevated Reporting Limit due to high concentration.
d2	Indicates the analyte has elevated Reporting Limit due to matrix.
e	Indicates the reported concentration is estimated.
g	Indicates the sample concentration was quantitated using a gasoline standard.
h	Indicates the sample was analyzed past recommended holding time.
i	Insufficient spike concentration due to high analyte concentration in the sample.
j	Indicates the reported concentration is below the Reporting Limit.
k	Indicates the sample concentration was quantitated using a kerosene standard.
l	Indicates an MS/MSD was not analyzed due to insufficient sample. An LCS / LCS Duplicate provided for precision.
m	Indicates the sample concentration was quantitated using a mineral spirits standard.
o	Indicates the sample concentration was quantitated using a motor oil standard.
p	Indicates the sample was post spiked due to sample matrix.
q	Indicates MS/MSD exceeded control limits. The associated sample may exhibit similar matrix bias. All other quality control indicators are in control.
r	Indicates the sample was received past recommended holding time.
u	Indicates the sample was received improperly preserved and/or improperly contained.
uj	Indicates the result is below the Reporting Limit and is considered estimated.
z	Indicates the BOD dilution water blank depletion was between 0.2 and 0.5 mg/L.

TestAmerica INCORPORATED

Indianapolis Division
69640 Hillsdale Court
Indianapolis, IN 46250

Phone: 317-842-4261
Fax: 317-842-4286

To assist us in using the proper analytical methods, is this work being conducted for regulatory purposes?
Compliance Monitoring ____

Client Name: Donan Client #: ____
Address: ____
City/State/Zip Code: Jasper
Project Manager: Ed Knust
Telephone Number: ____ Fax: 812 482 9165
Sampler Name: (Print Name) ____
Sampler Signature: Ed Knust

Project Name: Brush Creek
Project #: ____
Site/Location ID: ____ State: ____
Report To: ____
Invoice To: ____
Quote #: ____ PO#: ____

TAT
__ Standard
__ Rush (surcharges may apply)

Date Needed: ____

Fax Results: Y N

SAMPLE ID	Date Sampled	Time Sampled	G = Grab, C = Composite	Field Filtered	Matrix: SL - Sludge DW - Drinking Water GW - Groundwater S - Soil/Solid WW - Wastewater Specify Other	HNO_3	HCl	NaOH	H_2SO_4	Methanol	None	Other (Specify)	Nitrate Nitrite	TKN	Ammonia	Total Phos	Dissolved Phos	Turbidity					REMARKS
1	6/6/01		G		Str water				1		1												
2									1		1												
3									1		1												
4									1		1												
5									1		1												
6									1		1												
7									1		1												
8									1		1												
9									1		1												
10									1		1												

QC Deliverables
__ None
__ Level 2 (Batch QC)
__ Level 3
__ Level 4
Other: ____

Special Instructions:

Relinquished By:	Date:	Time:	Received By:	Date:	Time:
Ed Knust	6/6/01	1745	Nathan Hurley	6/7/01	10:10

LABORATORY COMMENTS:
Init Lab Temp: 15.4°C
Rec Lab Temp:
Custody Seals: Y N N/A
Bottles Supplied by TestAmerica: Y N
Method of Shipment:

XI. 4 FECAL COLIFORM ANALYSIS RESULTS

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #1.

BECKMAR CERTIFICATE OF ANALYSIS # 69007

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time	Analyst
Fecal Coliform	*20*	col/100ml	G	SM9222d	6/6/01 17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY
Jeffersontown Business Park
3259 Buckhorn Parkway
Jeffersontown, KY 40299
502 ...
F...

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac
Lab Code E87631

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #2.

BECKMAR CERTIFICATE OF ANALYSIS # 69008

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*140*	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you.

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #3.

BECKMAR CERTIFICATE OF ANALYSIS # 69009

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time	Analyst
Fecal Coliform	< *20*	col/100ml	G	SM9222d	6/6/01 17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #4.

BECKMAR CERTIFICATE OF ANALYSIS # 69010

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*2320*	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

Lab Code E87631

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #5.

BECKMAR CERTIFICATE OF ANALYSIS # 69011

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	***2680***	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #6.

BECKMAR CERTIFICATE OF ANALYSIS # 69012

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*2280*	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #7.

BECKMAR CERTIFICATE OF ANALYSIS # 69013

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*1480*	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

ENVIRONMENTAL LABORATORY

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #8.

BECKMAR CERTIFICATE OF ANALYSIS # 69014

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*1480*	col/100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

Beckmar

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #9.

BECKMAR CERTIFICATE OF ANALYSIS # 69015

Sample Date: 6/6/01
Sample Time: 11:45
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*1400*	col 100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

ENVIRONMENTAL LABORATORY
Jeffersontown Business Park
3251 Rockingham Parkway
Louisville, KY 40299

Beckmar

ENVIRONMENTAL LABORATORY

Date of Issue: June 08, 2001

Donan Engineering
4342 North Hwy 231
Jasper, IN 47546

RE: Analysis results for: Brush Creek: #10.

BECKMAR CERTIFICATE OF ANALYSIS # 69016

Sample Date: 6/6/01
Sample Time: 16:15
Sampled by: Mr. Ed Knust

Parameter	Results	Units	Type	Method	Analyzed Date / Time		Analyst
Fecal Coliform	*960*	col 100ml	G	SM9222d	6/6/01	17:45	PDB

Remarks:

If you have any questions please call.

Thank you,

Robin R. Burch

Robin R. Burch
Quality Control Officer

RRB:dwt

All results meet the requirements of the NELAC Standards

ACCREDITED IN ACCORDANCE WITH nelac

Lab Code E87631

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300076 4			08/08/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.5		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	<0.020		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.14		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	18		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300077 5			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.82		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.24		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.059		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	6.0		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300084 11			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.85		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.24		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.054		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	5.4		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300085 DAM			08/08/2001				
Nitrogen, Ammonia	77		mg/kg	cdk	08/15/2001 07:14	EPA 350.1	<5.0
Nitrogen, Kjeldahl	430	d1x10	mg/kg	cdk	08/15/2001 10:08	EPA 351.2	<150
Nitrogen, Nitrate	0.70		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Nitrate+Nitrite	0.38		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Total	430		mg/kg	sld	08/16/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	08/14/2001 11:00		Complete
Phosphorus, Total	130	d1x10	mg/kg	tpd	08/14/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
Distillation, Ammonia	Complete			cdk	08/13/2001 13:35		Complete

T-4 11-j

DONAN ENGINEERING CO., INC.

CHAIN OF CUSTODY FORM

☐ R.R. 3, BOX 40H – U.S. HIGHWAY 231 NORTH
JASPER, INDIANA 47546
(812)482-5611 Fax (812)482--9165

☐ 920 VINE STREET
EVANSVILLE, INDIANA 47708
(812)422-7456 Fax (812)422-7488

Co. Name:

Project Name: Brush Creek

Quote No.: PO No.:

ENVIRONMENTAL PROGRAM:

CWA NPDES ____ IWP ____ SLUDGE ____

RCRA MW ____ SW ____ DISPOSAL ____

SDWA ____ CERCLA/SUPERFUND ____ OTHER ____

Sampled by:

Analyses Requested (Note special detection limits or methods)

Report To:
Co.
Add.
Attn.
Phone.

Accelerated Turnaround Requested ____
Subject to Additional Charge)

Result Requested by: ____
Mo Day Yr
(Date must be Accepted and Approved by Lab)

Sample ID:	Date:	Time:	Comp	Grab	Sample Description:	No. of Containers	Fecal coliform									Remarks:	EMS Sample No.
1	9/6/01	1145		✓	sfc water		✓									69007	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10		1615														69016	

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Ed Knust	1/6/01 1730	Paul D. Bach			
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Remarks:		

XI. 5 BASELINE SAMPLES ANALYTICAL REPORTS

TestAmerica
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ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job Number: 01.04207

Enclosed are the Analytical Results for the following samples submitted to TestAmerica, Inc. Indianapolis Division for analysis:

Project Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number	Sample Description	Date Taken	Time Taken	Date Received
300072	EPILIMNION	08/08/2001		08/10/2001
300073	HYPOLIMNION	08/08/2001		08/10/2001
300074	2	08/08/2001		08/10/2001
300075	3	08/08/2001		08/10/2001
300076	4	08/08/2001		08/10/2001
300077	5	08/09/2001		08/10/2001
300078	6	08/09/2001		08/10/2001
300079	7	08/09/2001		08/10/2001
300080	8	08/09/2001		08/10/2001
300081	9	08/09/2001		08/10/2001
300082	9U	08/09/2001		08/10/2001
300083	10	08/09/2001		08/10/2001
300084	11	08/09/2001		08/10/2001
300085	DAM	08/08/2001		08/10/2001
300086	2	08/08/2001		08/10/2001
300087	3	08/08/2001		08/10/2001
300088	4	08/08/2001		08/10/2001

TestAmerica, Inc. certifies that the analytical results contained herein apply only to the specific samples analyzed.

TestAmerica Incorporated-Indianapolis Division is in compliance with the National Environmental Laboratory Accreditation Program (NELAP) Standards.

Reproduction of this analytical report is permitted only in its entirety.

Project Representative

TestAmerica
INCORPORATED

ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300072 EPILIMNION			08/08/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.5		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.026		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.080		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	7.8		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300073 HYPOLIMNION			08/08/2001				
Nitrogen, Ammonia	3.9		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	4.9		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.020		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.40		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.13		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	20		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300074 2			08/08/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.2		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	<0.020		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.065		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	11		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300075 3			08/08/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.3		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	<0.020		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.091		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	12		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300078 6			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.57		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.11		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	<0.05		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	2.0		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300079 7			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.43		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.30		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	<0.05		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	2.3		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
DONAN ENGINEERING
4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300080 8			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.49		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	1.4		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.052		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	4.3		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300081 9			08/09/2001				
Nitrogen, Ammonia	0.36		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	1.6		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.25		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.20		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	34		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
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4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300082 9U			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.96		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.26		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.12		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	<0.05		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	2.2		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
300083 10			08/09/2001				
Nitrogen, Ammonia	<0.10		mg/L	cdk	08/15/2001 08:15	EPA 350.1	<0.10
Nitrogen, Kjeldahl	0.99		mg/L	cdk	08/15/2001 10:08	EPA 351.2	<0.30
Nitrogen, Nitrate+Nitrite	0.49		mg/L	cdk	08/17/2001 07:43	EPA 353.2	<0.020
Phosphorus, Total	0.086		mg/L	tpd	08/14/2001 11:00	EPA 365.2	<0.05
Phosphorus, Dissolved	0.052		mg/L	tpd	08/15/2001 11:00	EPA 365.2	<0.05
Phosphorus, Total - Prep	Complete			tpd	08/14/2001 11:00		Complete
Turbidity	19		NTU	rdk	08/10/2001 11:00	EPA 180.1	<1.
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete

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ANALYTICAL REPORT

Mr. Ed Knust
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4342 North US 231
Jasper, IN 47546

08/17/2001

Job No.: 01.04207

Date Received: 08/10/2001
Job Description: PROJ# J01-02-032 BRUSH CREEK

Sample Number / Sample I.D. Parameters	Wet Wt. Result	Flag	Sample Date/ Units	Analyst	Date & Time Analyzed	Method	Reporting Limit
300086 2			08/08/2001				
Nitrogen, Ammonia	85		mg/kg	cdk	08/15/2001 07:14	EPA 350.1	<5.0
Nitrogen, Kjeldahl	650	d1x10	mg/kg	cdk	08/15/2001 10:08	EPA 351.2	<150
Nitrogen, Nitrate	0.30		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Nitrate+Nitrite	0.76		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Total	650		mg/kg	sld	08/16/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	08/14/2001 11:00		Complete
Phosphorus, Total	65	d1x10	mg/kg	tpd	08/14/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
Distillation, Ammonia	Complete			cdk	08/13/2001 13:35		Complete
300087 3			08/08/2001				
Nitrogen, Ammonia	150		mg/kg	cdk	08/15/2001 07:14	EPA 350.1	<5.0
Nitrogen, Kjeldahl	980	d1x10	mg/kg	cdk	08/15/2001 10:08	EPA 351.2	<150
Nitrogen, Nitrate	<0.10		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Nitrate+Nitrite	0.32		mg/kg	cdk	08/16/2001 08:22	EPA 353.2	<0.10
Nitrogen, Total	980		mg/kg	sld	08/16/2001	EPA 351.4/E-	
Phosphorus, Total NA - prep	Complete			tpd	08/14/2001 11:00		Complete
Phosphorus, Total	130	d1x10	mg/kg	tpd	08/14/2001 11:00	EPA 365.2	<25.0
Digestion, TKN	Complete			cdk	08/14/2001 09:50		Complete
Distillation, Ammonia	Complete			cdk	08/13/2001 13:35		Complete

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KEY TO ABBREVIATIONS

<	Less than; when appearing in the result column, indicates analyte not detected at or above the Reporting Limit.
%	Percent; To convert ppm to %, divide result by 10,000. To convert % to ppm, multiply the result by 10,000.
*	Indicates the Reporting Limit is elevated due to insufficient sample volume.
mg/L	Part per million; Concentration in units of milligrams of analyte per Liter of aqueous sample.
ug/L	Part per billion; Concentration in units of micrograms of analyte per Liter of aqueous sample.
mg/kg	Part per million; Concentration in units of milligrams of analyte per kilogram of non-aqueous sample.
ug/kg	Part per billion; Concentration in units of micrograms of analyte per kilogram of non-aqueous sample.
a	Indicates the sample concentration was quantitated using a diesel fuel standard.
b	Indicates the analyte of interest was also found in the method blank.
c	Sample resembles unknown Hydrocarbon.
dw	When indicated, the result is reported on a dry weight basis. The contribution of the moisture content in the sample has been subtracted when calculating the concentration.
d1	Indicates the analyte has elevated Reporting Limit due to high concentration.
d2	Indicates the analyte has elevated Reporting Limit due to matrix.
e	Indicates the reported concentration is estimated.
g	Indicates the sample concentration was quantitated using a gasoline standard.
h	Indicates the sample was analyzed past recommended holding time.
i	Insufficient spike concentration due to high analyte concentration in the sample.
j	Indicates the reported concentration is below the Reporting Limit.
k	Indicates the sample concentration was quantitated using a kerosene standard.
l	Indicates an MS/MSD was not analyzed due to insufficient sample. An LCS / LCS Duplicate provided for precision.
m	Indicates the sample concentration was quantitated using a mineral spirits standard.
o	Indicates the sample concentration was quantitated using a motor oil standard.
p	Indicates the sample was post spiked due to sample matrix.
q	Indicates MS/MSD exceeded control limits. The associated sample may exhibit similar matrix bias. All other quality control indicators are in control.
r	Indicates the sample was received past recommended holding time.
u	Indicates the sample was received improperly preserved and/or improperly contained.
uj	Indicates the result is below the Reporting Limit and is considered estimated.
x	Indicates the BOD dilution water blank depletion was between 0.2 and 0.5 mg/L.

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XI. 6 PLANKTON & CHLOROPHYLL DATA REPORTS

Brush Creek Water Analysis Summary
August 8, 2001

Introduction

The water analysis of Brush Creek was performed for Donan Engineering Company Incorporated. The analyses included chlorophyll, phytoplankton and zooplankton.

Methods

Two hundred milliliters of water from the Brush Creek epilimnion and from the hypoliminion were collected and filtered for chlorophyll analysis by Donan Engineering. Samples were collected in duplicate. The filters were wrapped in foil to prevent light from destroying the chlorophyll and sent to the Water Research Laboratory (WRL) at Northern Kentucky University. Upon receipt of the filters at the WRL, they were logged in and extracted in 10 milliliters of acetone over night (American Public Health Association et al. 1998). The extracted chlorophyll was analyzed using a Spec 20 at wavelengths 665 nm and 750 nm to determine the concentrations of chlorophyll:

$$\frac{\text{Absorbance coefficient*absorbance*volume extracted}}{\text{Volume filtered * path length}}$$

Five feet by five inch Plankton tows (19,300 mL filtered) were collected in 120 millillter jars by Donan Engineering and sent to the WRL for phytoplankton and zooplankton analysis. Samples were collected in duplicate and Lugols Iodine solution was immediately added to each bottle as a preservative. Upon receipt of the samples at the WRL, they were logged in and settled in Utermöhl plankton chambers over night (Wetzel and Likens 1991). A qualitative and quantitative analysis was performed at 200X for the phytoplankton and 100X for the zooplankton using a Wild M40 inverted microscope (Chorus and Bartram 1999). Algal identification was made using standard taxonomic references such as Prescott (1982) and others available at the Northern Kentucky University Diatom Herbarium and Water Lab. Zooplankton identification was made using standard taxonomic references such as Eddy and Hodson (1982). The number of algal units were counted within a field using a whipple disk. Counting was continued until 300 whipple fields or 300 algal units were attained for the algal analysis and until at least 70 whipple fields were attained for the zooplankton analysis. Less fields are required at a lower magnification power. The plankton density (units/mL) was determined by applying the following formula:

$$\left[\frac{\text{\# of cells}}{\text{volume of utermohl}}\right] * \left[\frac{\text{area of utermohl}}{\text{(area of whipple disk X \# of fields)}}\right] * \left[\frac{\text{volume collected}}{\text{volume filtered}}\right]$$

A unit of algae is based on the natural unit count according to the Standard Methods 10200F (American Public Health Association et al. 1998). The data were analyzed using Excel®.

Results and Discussion

The New South Wales (NSW) Blue-Green Algae Task Force has established algal alert levels to minimize the impacts of toxic cyanobacteria for general water supplies (Yoo et al. 1995). The NSW Task Force has established three alert levels:

LEVEL	UNITS/mL	ALERT FRAMEWORK
1	500-2,000	Identify the type of algae
2	2,000-15,000	Confirm type-Look for metabolites
3	Above 15,000	Implement appropriate treatment

We use the low end of Alert Level 2 (2000 algal units/mL) as an alarm level. However, neither of the samples even reached alarm level 1 (**Figure 1**). Both of the Brush Creek samples were dominated by blue-green algae (**Figure 1**). The 0-5 sample consisted of about 44% blue-green algae and the 5-10 sample was consisted of about 46%. Blue-green algae are often taste and odor indicators for drinking water facilities as well as toxin producers. Thirty-two percent of each sample was *Aphanizomenon*, a filamentous blue-green algae that is capable of producing toxins and taste and odor episodes (**Figure 2** and **Figure 3**). The chlorophyll readings are not consistent with a typical stratified lake. It is uncharacteristic for the hypoliminion at 4 µg/L to have a higher concentration of chlorophyll than the epilimnion at 0 µg/L. However, chlorophyll values below 5 µg/L are considered insignificant. Also, incorrect filters were used to filter the water for the chlorophyll analyses which may have affected the results.

Of the zooplankton, both of the Brush Creek samples were dominated by rotifers (**Figure 4**). A dominance of rotifers indicates a high density of small planktivorous fish or a low density of larger carnivorous fish. According to food chain dynamics, a high density of small planktivorous fish will reduce the density of the larger zooplankton, such as copepods or cladocera, that feed on smaller zooplankton such as rotifers (Stiling1992). Furthermore, there may be few large fish to reduce the population of the smaller planktivorious fish. Also, rotifers are inefficient filter feeders. They are unable to feed on larger algae such the filamentous *Aphanizomenon* that dominates the Brush Creek samples.

Literature Cited

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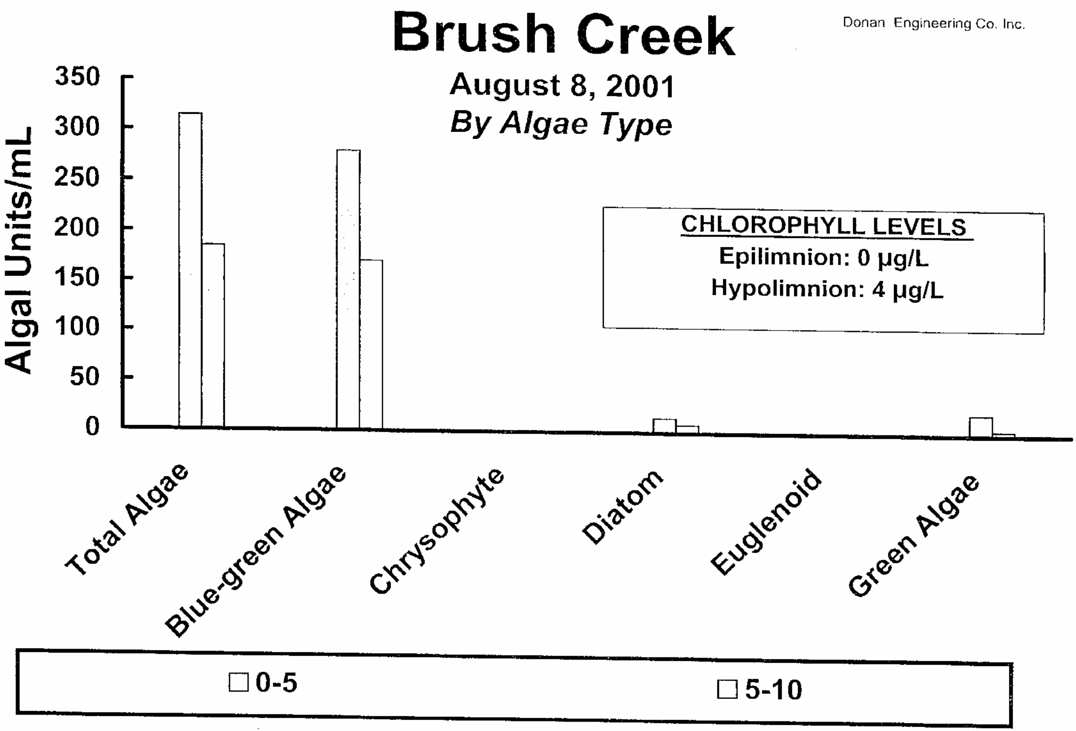

Figure 1. The total algal density for the 0-5 sample reached 630 units/mL of which 280 units/mL were blue-green algae. The total algal density for the 5-10 sample reached 370 units/mL of which 171 were blue-green algae.

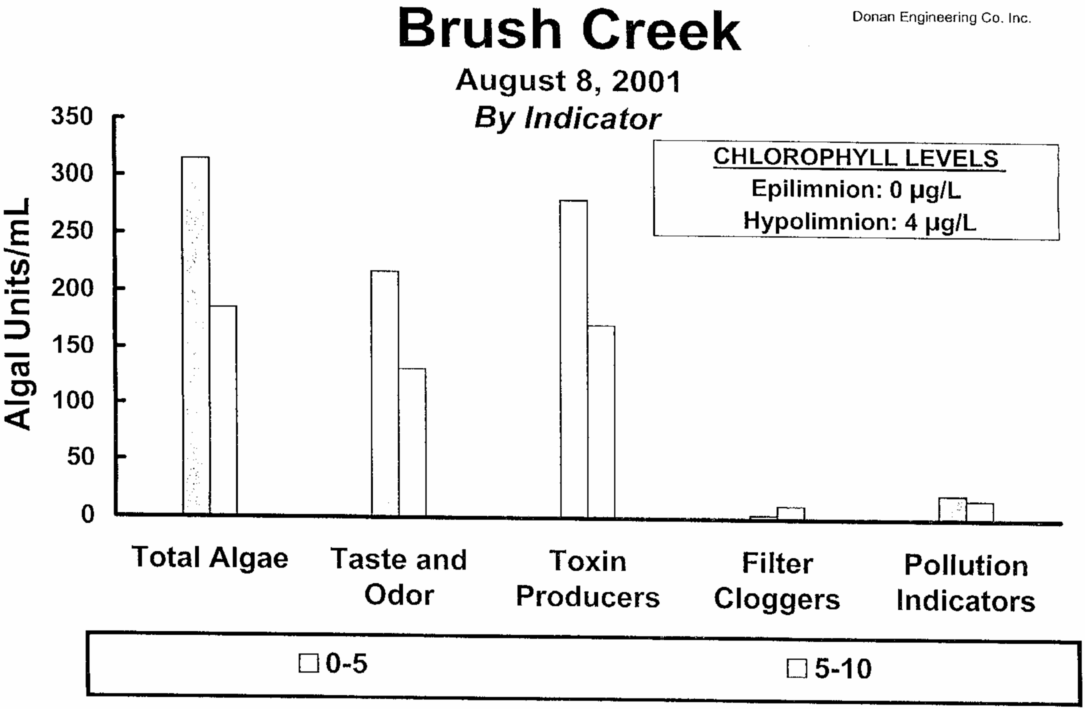

Figure 3. The dominant algae, *Aphanizomenon,* in both the 0-5 and the 5-10 sites are known to produce taste and odor episodes for drinking water utilities as well as produce toxins.

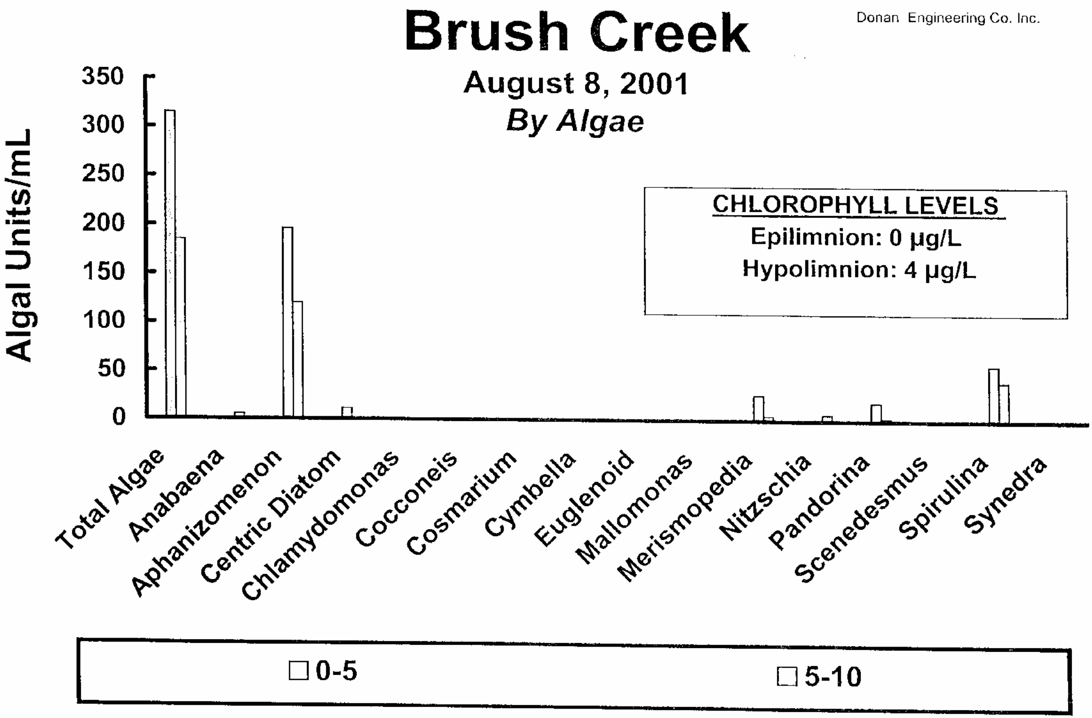

Figure 2. Thirty-two percent of the algal density for both the 0-5 and the 5-10 sites were *Aphanizomenon*, a blue-green algae.

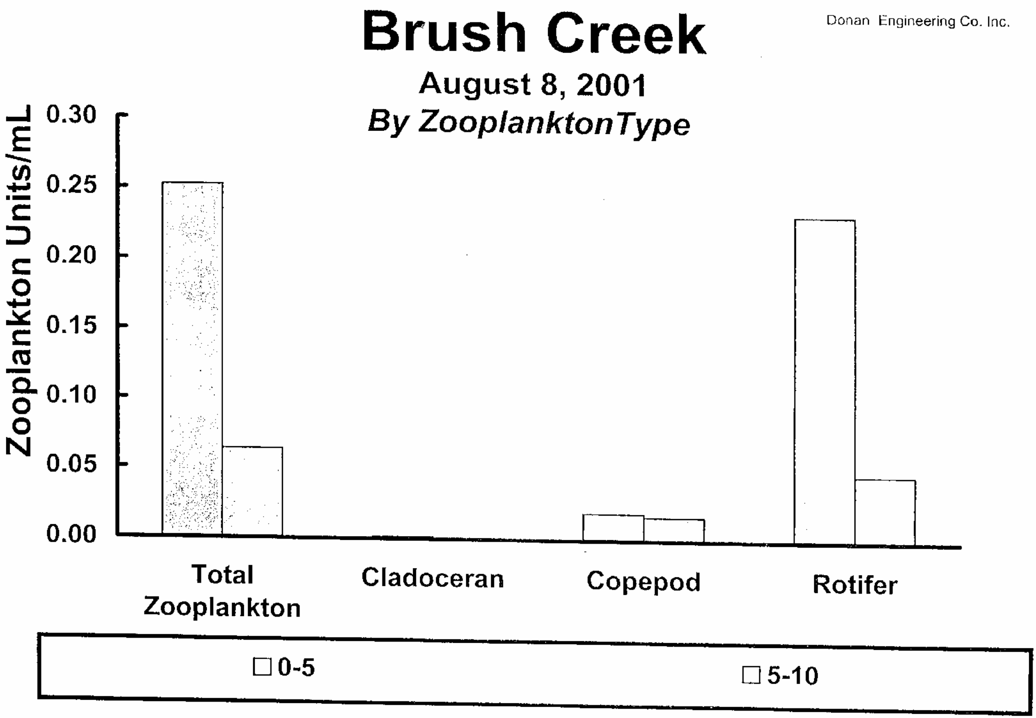

Figure 4. Rotifers were the dominant zooplankton in both the 0-5 and the 5-10 sites.

Donan Engineering, Inc.

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September 22, 2000

Dale A. Gick
Section Head, Project Development
IDNR-Division of Water
402 W. Washington St., Room W264
Indianapolis, IN 46204

SEP 2000
RECEIVED
DNR
DIV. OF WATER

RE: Brush Creek Reservoir
Diagnostic Study

Dear Mr. Gick:

I appreciate being contacted by Ms. Jomary Crary regarding the diagnostic study for Brush Creek Reservoir and its watershed. Based on the information provided, it is my understanding that the study is to follow the same guidelines as projects funded by the Lake and River Enhancement Program. We further understand however, that the focal point for this project has more to do with sedimentation within the reservoir and the resultant loss of storage capacity that go well beyond concerns of water quality degradation. At your request, I have prepared our proposal for that project and feel confident we will be able to finalize a scope of services that deals with the issues of Brush Creek Reservoir for a suitable budget.

Donan can provide the services required with staff that includes professionals who have expertise in virtually all disciplines necessary to complete diagnostic/feasibility studies, engineering feasibility studies, designs, and construction engineering. Our firm has extensive experience in Lake & River Enhancement Projects and we are currently working on a construction/design project and post-construction monitoring project for two lakes funded by the Indiana Department of Natural Resources-Lake and River Enhancement Program.

Past and current projects include:

West Boggs Lake	Loogootee, IN	Post Construction Monitoring	2000
Lake Lemon	Unionville, IN	Design/Construction	1999
Indian Creek	Bedford, IN	Diagnostic Study	1998
Barbee Lake	Leesburg, IN	Design Study	1996
Dubois Co. Park & Rec.	Jasper, IN	Lake & Wetland Design	1996
Lake Winona	Warsaw, IN	Design Study	1995

West Boggs Lake	Loogootee, IN	Feasibility Study	1992
Lake Salinda	Salem, IN	Feasibility Study	1990
Prides Creek	Petersburg, IN	Design Study	1990
Prides Creek	Petersburg, IN	Feasibility Study	1989
Beaver Creek Lake	Jasper, IN	Feasibility Study	1989
Huntingburg Lake	Huntingburg, IN	Feasibility Study	1989

In addition to erosion control structures for these projects, our firm has designed literally hundreds of sediment and stormwater management structures for watersheds throughout Indiana and surrounding states.

The diversity and expertise of Donan can be most beneficial to the Division of Water (DOW) on this project. We are currently finalizing a few projects that have required prolonged involvement by staff members. Given notice to proceed, we can ***immediately*** begin to collect lake and watershed information for the diagnostic study project. We have the resources to allocate to the tasks of the project so that they are accomplished as scheduled. We are not so large though, that we have lost flexibility. What that means to you is that we can be responsive to the needs of the DOW, the NRCS, the City of North Vernon, and the Muscatatuck State Developmental Center.

We look forward to hearing from you. If there are questions or comments on the scope of services proposed, please don't hesitate to contact us. Please note that the services proposed, as well as the fees, are **NEGOTIABLE**. Donan will be glad to meet with the DOW to further define a scope of services that are mutually agreeable. It is not only our intent to work *for* your agency; we want to work *with* you. We appreciate your confidence in our service.

Sincerely,

Donan Engineering, Inc.

Ed Knust

Edward J. Knust, CPAg.
Senior Environmental Project Manager

TABLE OF CONTENTS

INTRODUCTION

A Diagnostic Study is proposed for Brush Creek Reservoir and the subwatersheds in Jennings County in Indiana. The project is intended to describe conditions and trends in Brush Creek Reservoir and the subwatersheds and to identify potential sedimentation and water quality problems in subwatersheds. This assessment is to provide guidance for future land treatment project selection and to predict the impacts of those projects to sediment loading and water quality degradation to Brush Creek Reservoir. Donan Engineering, Inc. (Donan) concurs with the diagnostic study approach recommended for the watershed of Brush Creek Reservoir to compile information on land use, water quality, recommendations for treatment, and expectations for success of those treatments as well as prioritization of the treatments. This proposal includes a workscope to:

1. Summarize historical information on trends in land use and water quality.
2. Map and describe current conditions.
3. Collect and analyze information on water quality, biology, and habitat.
4. Evaluate nonpoint source pollution in lakes and subwatersheds.
5. Prioritize management recommendations.
6. Create a public information handout.
7. Facilitate a final public meeting.
8. Report project progress.
9. Complete lake diagnostic study report.

PROJECT DESCRIPTION

In preparing our quote for the project, I have attempted to predict the cost of the services required to accomplish the project tasks identified in the LARE program scope of services. The project tasks and the predicted fees to accomplish them are as follows:

1. Summarize historical information on trends in land use and water quality.

$1,800.00

Donan will review land use data, Division of Fish & Wildlife surveys and information, recreational use information, volunteer monitoring data, and other available reports to summarize and compile this information. An annotated bibliography will be prepared from this available information and a brief summary will be included pertaining to water quality and contributing factors.

2. Map and describe current conditions.

$4,200.00

Maps will be prepared which depict current conditions in Brush Creek Reservoir and the subwatersheds. Features of the maps may include inherent soil properties pertaining to erosion potential and hydric soil conditions and surface features such as flood management areas, natural ecological settings, and locations of known habitat and populations of state and federally listed species. If identified, point sources of pollutants may be included related to industry, sewage disposal, and/or mismanaged land usage.

A survey of the land uses and management techniques on Brush Creek Reservoir watershed will be conducted. Verification of residential, agricultural, forest, commercial and recreational landuses will be made. The landuses will be analyzed by subwatersheds, and for the entire watershed. Fertilization methods, cropping and tillage practices, and grazing and feedlot areas will also be documented and evaluated.

Best Management Practices (BMPs) which are nonstructural and low-structural measures that are determined to be the most effective, practical means of preventing or reducing pollution inputs from nonpoint sources in order to achieve water quality goals, can be recommended for the Brush Creek Reservoir watershed.

The application and selection of the BMPs should be based on:

- Type of land-use activity
- Physical conditions in the watershed
- Pollutants to be controlled
- Site-specific conditions

In general, BMPs can be divided into three groups:

- source control measures
- collection control and reduction of delivery, and
- treatment of runoff.

The methods in these three groups will be evaluated when considering which BMPs should be implemented. The above methods are listed as options for watersheds in general. Once the watershed has been evaluated, specific appropriate methodology will be recommended for specific areas of the Brush Creek Reservoir watershed.

3. Collect and analyze information on water quality, biology, and habitat.

$9,900.00

a. Water Quality

<u>Lake Pool Sampling</u>

This task will include water quality testing in the form of *in-situ* reservoir water sampling. The lake pool water quality parameters will be selected consistent with the Indiana Department of Environmental Management's (IDEM) publication entitled, *Lake Classification System and Management Plan*. This will specifically include Secchi depth, conductivity, pH, temperature, dissolved oxygen, nitrate + nitrite, organic nitrogen (TKN), total and dissolved phosphorus, turbidity, plankton, and chlorophyll-a. In addition, a vertical profile of temperature and dissolved oxygen at 1 meter intervals would be taken at the same locations. The results of the lake pool sampling will be used to assess the lake's current Eutrophication Index Value, as well as to assess plankton composition and other lake conditions affecting water quality. Donan will collect surface and bottom samples from the deepest area of Brush Creek Reservoir. This general location will be determined based on review of bathymetric maps available for the Brush Creek Reservoir and input from the DOW and others involved in the project.

Tributary Sampling

After a significant storm event, stormwater samples will be collected to conduct testing of physical, chemical, and biological parameters. Specifically, this will include analyzing each sample for pH, temperature, dissolved oxygen, nitrate + nitrite, organic nitrogen (TKN), total and dissolved phosphorus, turbidity, and conductivity. The collected samples will also be assessed for fecal coliform entering Brush Creek Reservoir. Grab samples at these locations, and from the deepest area of the lake, will be analyzed for fecal coliform to assess contamination. In addition, baseflow monitoring will be measured and reported. Donan Engineering will analyze samples from three (3) inlets including Brush Creek to the northeast and two unnamed tributaries along the east side of the reservoir.

b. Habitat Evaluation

Donan will perform soundings at the three inlets of the reservoir to calculate existing bathymetric contours. These will be compared with the contours plotted on existing bathymetric maps. An evaluation of sediment deposition at other areas may be in order to assess nutrient loading associated with the sediment, restrictions to boating due to depth reductions, economic considerations to the farmer, aesthetic considerations, and, especially, storage capacity of the reservoir. Donan will present maps of depth contours, depth to volume curves, and area to volume curves. Donan will also calculate a water budget for the reservoir. Donan will also map reservoir shoreline protection and erosion areas, indicating the approximate extent and distribution of existing shoreline stabilization measures.

c. Biological Community and Quality

Fish and macroinvertebrate communities

Donan will include reports and a brief analysis of surveys, trends, and management recommendations from available studies conducted on the lake and tributaries. This assessment is to be based on existing, available data and will serve to provide an indication of water quality trends in Brush Creek Reservoir. Donan will meet with DNR fisheries biologists and others regarding Brush Creek Reservoir to obtain information about aquatic populations of the lake, both botanical and zoological.

Aquatic plants.

Donan will conduct an aquatic plant survey and prepare an aquatic plant distribution map for Brush Creek Reservoir. It is important to assess the quality and quantity of these aquatic plants. Many species of aquatic plants have positive impacts on the fish populations and overall water quality of the reservoir. However, having aquatic plant species in the wrong places of a reservoir or having an overpopulation of certain species can have negative effects.

Many of these areas that contain aquatic plants may function as wetlands. Properly maintained and/or properly designed wetlands can have many positive impacts on water quality. Wetlands are often referred to as "the kidneys of the landscape" for the functions they perform in hydrologic and chemical cycles. Wetlands have been found to cleanse polluted waters, prevent floods, protect shorelines, and recharge groundwater aquifers. Furthermore, wetlands play major roles in the landscape by providing unique habitats for a wide variety of flora and fauna.

It is important to recognize that wetlands are not considered a watershed management tool, but rather an in-lake treatment process. Therefore, wetlands alone would only address the symptoms and not correct the cause of the water quality problems. After watershed management alternatives have been identified, the restoration or construction of wetlands will be analyzed. Wetlands will often provide a very effective final filtration system before the water enters a reservoir.

Sedimentation basins can often be constructed in conjunction with a wetland area. These basins would provide a mechanism to collect the sediment before it enters the wetland. This would extend the life expectancy and the efficiency of the wetland. A survey will be conducted to assess and map the extent to which wetlands are already present. Photographic documentation will be made. Analysis of the existing wetlands, and the need for constructed wetlands will be provided in the final report, as well as associated costs.

Donan Engineering has experience in designing many erosion control structures including, but not limited to, diversion ditches, sedimentation basins, and wetlands. When the same firm that conducted the diagnostic or feasibility study is capable of implementing the design phase of a project, there is a better understanding of the work that is required. This is a strong asset of Donan Engineering.

Nuisance species

If invasive, nuisance botanical or zoological species are identified as concerns in the lake or watershed, a survey of the current count, or distribution, of the species will be conducted on a representative day.

d. Trends analysis

Once these various evaluations are completed, trends will be analyzed to attempt to identify relationships between physical, chemical, habitat, and biological quality. This information will be relied on, in part, to identify limiting, or otherwise controlling, factors.

4. Evaluate nonpoint source pollution in subwatersheds.

$3,200.00

Subwatersheds suspected of being significant contributors to water quality degradation may be evaluated so as to identify the need for adjustments to land use management practices and the benefits which could be realized by their implementation. A Vollenweider nutrient loading figure will be included with an interpretation.

5. Prioritize management recommendations

$1,400.00

After identifying subwatersheds suspected of being the most significant contributors of pollutants, Donan can prioritize areas based on their predicted degradation to water quality. Physical and social characteristics of areas of the subwatersheds dictate the feasibility of the type of land treatments selected and these factors will be considered. Proposed land treatments could be ranked according to their potential benefits to water quality, their feasibility of implementation, and their cost effectiveness. Selected land treatment measures can be evaluated to determine approximate cost of implementation and realistic timetables.

Donan can provide assistance to pursue funding for the projects proposed from appropriate sources at various levels. Additional assistance can be provided to determine realistic funding objectives for the Association. It is recognized that, in many situations, the availability of grant or other funding is linked to the sponsoring organization's ability to match funds. The ability and willingness to match funds is generally regarded as a demonstration of support of the project to satisfy the funding source(s) that the funds will be used productively.

6. Create a Public Information Handout

$1,100.00

Donan will develop an information handout that addresses factual issues concerning the state of Brush Creek Reservoir and the costs or benefits predicted from proposed projects.

7. Facilitate public meeting.

$1,100.00

Donan can assist with organizing and attend a public meeting to present the final report. This meeting will provide opportunity for public comment as well as information exchange. Donan can create specialized mechanisms to help the public visualize and understand goals and objectives using three-dimensional animation computer renderings and other effective methods.

8. Report project progress.

$1,000.00

Donan can provide progress reports to the DOW after significant milestones of the project have been completed, or bi-monthly, as is agreeable to the DOW and other agencies involved.

9. Complete lake diagnostic study report.

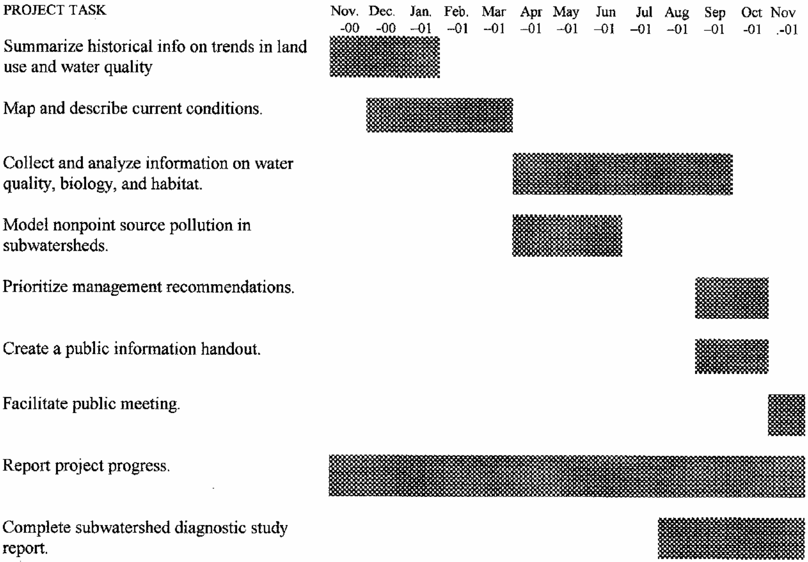
$4,000.00

This report is to contain details of how the previous eight project tasks were accomplished and supporting documentation as appendices. The final report will bring the DOW and proposed watershed land treatment projects to the point of engineering feasibility and design consideration.

Total Estimated Fees. $27,700.00

PROJECT OUTLINE/TIME SCHEDULE

A project outline/time schedule has been prepared in anticipation of accomplishing milestones of the project. This schedule has been prepared assuming DOW approval in the fall of 2000.



PROJECT COSTS

Donan Engineering Co., Inc. is very interested in performing this project for the DOW. The following table is an itemized list of fees applied to milestones of the project.

PROJECT COSTS

Summarize historical information on trends in land use and water quality.	$1,800.00
Map and describe current conditions.	$4,200.00
Collect and analyze information on water quality, biology, and habitat.	$9,900.00
Evaluate nonpoint source pollution in subwatersheds.	$3,200.00
Prioritize management recommendations.	$1,400.00
Create a public information handout.	$1,100.00
Facilitate public meeting.	$1,100.00
Report project progress.	$1,000.00
Complete lake diagnostic study report.	$4,000.00
	$27,700.00

Note: Our fees are negotiable based on the final approved scope of services mutually agreeable to the DOW and the consultant. This proposal is for a lump sum fee to be compensated by phase item as agreeable to the DOW and the consultant.

PROJECT TEAM

PRIMARY LAKE PROJECT TEAM MEMBERS

PROJECT ASSIGNMENT	NAME	FUNCTION
Principal	John G. Donan, Jr., P.E.	Principal Management
Project Engineers\ Managers	Edward J. Knust, CPAg	Soil Science/Hydrology/Erosion Control
	Steven R. Grundhoefer, P.E.	Hydraulics/Erosion Control
	Jason Hall, P.E.	Hydraulics
	William Franco, P.E.	Project Engineer
	Sandy Tsekouras, P.E.	Hydraulics
	Lyle J. Donan, E.I.	Project Engineer
	David K. Mills, L.S.	Registered Land Surveyor

Note: Other staff will be utilized as needed. The primary contact for this project will be Edward J. Knust, CPAg, Senior Environmental Project Manager.

MEMO

To: **Ed Knust, Donan Engineering**
From: **Jill Hoffmann, IDNR**
Cc: **Jomary Crary, Jim Farr**
Date: **03/28/02**
RE: **Brush Creek Diagnostic Study Review**

Ed,

I have recently spent some time reviewing the Brush Creek Draft Study. I apologize for the delay and hope you find the following comments useful to this study or future studies.

- Page ii please convert phosphorus loading data to lbs/acre/yr. Landowners more easily interpret this unit.
- Page ii and page 136 note that P levels were at least double the state standard; however, at present time, the state does not have a P standard for surface water. In fact, the state does not yet have any nutrient criteria set for surface waters. This is anticipated in the next 3-5 years. Therefore, corrections also need to be made on several pages throughout the chemical and Physical Water Quality sections. I am unsure if the "standards" cited are for effluent discharge, or drinking water, or some other specific use, but this needs to be cleared up to reflect their true application. Sometimes theses 'other type of' standards can be a helpful reference points if described properly, or sometimes another reference number can be used such as the P concentration at which we typically see algal bloom in lakes, etc., but only used within context.
- I would like to see some discussion/mapping that helps to put the water quality sampling sites in context in terms of the landscape (i.e. subwatersheds). Certainly the boundaries can be mapped for the subwatershed represented by sites 7,9 and 9U. Similarly, the discussion of the sample site data should help the reader make the link to land use. As an example, if water quality information severely degrades between sites 6 and 5, then the technical staff can conclude that a 'large' quantity of pollutants are coming from the landscape between those locations. The goal is to prioritize subwatersheds based on land use and water quality info, so that LARE and other programs can better target BMP implementation money.
- Data on page 79 suggested that the reservoir suffers from internal P loading. This should be noted since solutions for this are outside of what can be accomplished through watershed BMPs. This should not discount or make light of watershed BMPs, but total remediation of the reservoir to a healthier trophic state is limited given the internal loading from existing sediments.
- It is odd and concerning that no submersed plants were noted or mapped in the reservoir (pg 84). If this condition exists year round it would have a large impact on the fishery and would call into questions many other ecological parameters. A better investigation is warranted and plant survey data from Larry Lehman should also be included.
- Page 107 discusses septic systems. Locations of septics should be mapped for historical and scientific purposes. Given that no sewers are present in the watershed it can be assumed that all residences are on septic. Thus, aerial photos, permit information from the health department and/or census information would provide data to this end.

- Livestock Exclusion recommendations should reference *E. coli* and Ammonia levels. These recommendations need to be more focused based on what the land and water quality assessments told us.

I appreciate the time spent on this study, as well as the educational information presented within it. While my comments are focused on improvements, I did/do have many positive things to say about the report. I enjoyed the modeling data and am confident that the Districts have great supporting information/data to foster public participation in BMPs. If I can help with this, or other concluding activities, please call me.

Thanks for your time and hard work. If you have questions regarding any of my comments, please send me an email or call.

DIAGNOSTIC STUDY
FOR
BRUSH CREEK RESERVOIR WATERSHED

INTRODUCTION

The diagnostic study generally followed the guidelines developed by the Lake and River Enhancement Program of the DNR Division of Soil Conservation. The purpose of this diagnostic study then is to:

- Describe conditions and trends in Brush Creek Reservoir, Brush Creek, and the watershed.
- Identify potential nonpoint source water quality problems
- Propose specific direction for future work
- Predict and assess success factors for future work.

SETTING

Brush Creek Watershed
Relative & Actual Size by County

County	Acreage	Square Miles	% of Total
Jennings	4,990	7.8	54
Ripley	4,250	6.6	46
Total	9,240	14.4	100

Hydric Soils Acreage in Brush Creek Watershed

County	Hydric Soil	Hydric Soil Acreage	% of Watershed	% of Total Hydric Soil Acres
Jennings	Clermont	722	7.8	25.8
	Wakeland	25	0.2	0.9
Ripley	Cobbsfork	2031	22.0	72.7
	Wakeland	17	0.2	0.6
Total		**2795**	**30.2**	**100**

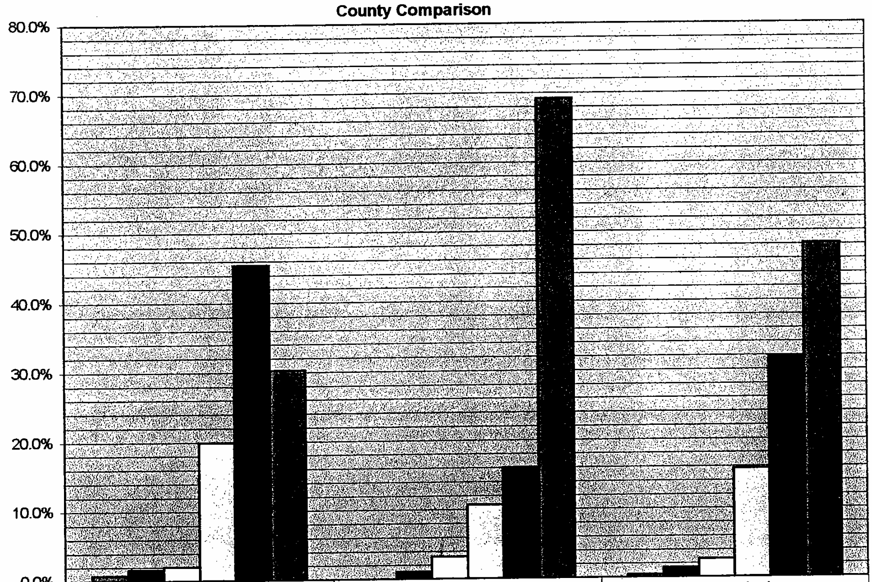
HEL Acreage in Brush Creek Watershed

County	Jennings	Ripley	Total
Acres in watershed	4990	4250	9240
% of County that is HEL	52.7	55.4	
HEL acreage in watershed (Assumes equal distribution of HEL acreage throughout county)	2630	2354	4984
			54%

EXISTING CONDITIONS

Landuse

Figure IV-6
Brush Creek Watershed Landuses
County Comparison



	Jennings County	Ripley County	Watershed
Commercial	0.8%	0.0%	0.4%
Water	1.6%	1.0%	1.3%
Residential	2.0%	3.2%	2.6%
Pasture	19.9%	10.7%	15.7%
Forest	45.4%	16.0%	31.9%
Cropland	30.2%	69.1%	48.1%

STREAM ANALYSIS

Brush Creek Reservoir/Watershed
Sampling Locations

Sample Point	Location	Quadrangle	County	Representing
1	Dam area of Reservoir	Butlerville	Jennings	Lake Pool
2	South inlet of Reservoir	Butlerville	Jennings	Sediment loading at public access boat ramp
3	Southeast inlet of Reservoir	Butlerville	Jennings	Unnamed tributary of Brush Creek, F&W area, and private land
4	Main inlet of Reservoir	Butlerville	Jennings	Brush Creek watershed
5	Brush Creek	Holton	Jennings	Cattle in stream, middle watershed
6	Brush Creek	Holton	Jennings	Background to cattle in stream, middle watershed.
7	Unnamed Tributary	Holton	Ripley	1,400 acre subwatershed
8	Brush Creek	Holton	Ripley	Upper watershed
9	Unnamed Tributary	Holton	Ripley	Cattle in Stream. Intensive agricultural land, upper area of subwatershed.
9U	Unnamed Tributary	Holton	Ripley	Background to Cattle in Stream. Intensive agricultural land, upper area of subwatershed.
10	Brush Creek	Holton	Ripley	Intensive agricultural land, upper watershed.

Table V-2
Base Flow

Reservoir

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
1	Pool	8.67	247	31.7	138	10.1	<0.10	1.5	0.026	1.5	1.526	0.08	<0.05	7.8
2	Boat Ramp	8.6	239	34.3	113	8.01	<0.10	1.2	<0.020	1.2	1.2	0.065	<0.05	11
3	East Inlet	8.68	256	34.8	115.9	8.6	<0.10	1.3	<0.020	1.3	1.3	0.091	<0.05	12
4	Brush Creek Inlet	8.58	302	34.2	122	8.55	<0.10	1.5	<0.020	1.5	1.5	0.14	<0.05	18

Brush Creek

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
5	Lower watershed	7.75	447	25.2	67	5	<0.10	0.82	0.24	0.82	1.06	0.059	<0.05	6
6	Mid watershed	7.77	415	24.7	75.6	6.2	<0.10	0.57	0.11	0.57	0.68	<0.05	<0.05	2
7	Lower south fork	7.9	535	28.2	123.4	9.62	<0.10	0.43	0.3	0.43	0.73	<0.05	<0.05	2.3
8	Lower north fork	7.8	522	25.1	90.6	7.38	<0.10	0.49	1.4	0.49	1.89	0.052	<0.05	4.3
9	upper south fork	7.7	560	28.9	23.2	1.76	0.36	1.6	0.25	1.24	1.85	0.2	<0.05	34
9U	9 background	7.7	530	28	89	6.8	<0.10	0.96	0.26	0.96	1.22	0.12	<0.05	2.2
10	upper north fork	7.68	492	25.8	85.1	6.3	<0.10	0.99	0.49	0.99	1.48	0.086	0.052	19
11	Duplicate 5	7.75	451	25.1	70	5.1	<0.10	0.85	0.24	0.85	1.09	0.054	<0.05	5.4

Table V-3

Storm Sampling

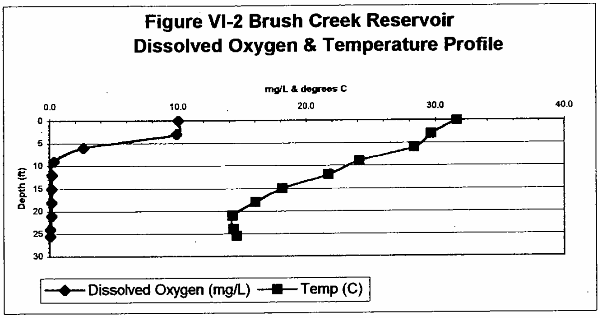
Reservoir

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
1	Pool	7.96	335	22.5	98.8	8.65	0.16	1.1	0.26	0.94	1.36	0.053	<0.050	3.29
2	Boat Ramp	7.85	343	21	113	9.59	0.16	1.1	0.472	0.94	1.572	0.066	<0.05	10.5
3	East Inlet	8.01	329	22.5	104	8.7	0.18	0.82	0.321	0.64	1.141	<0.050	<0.05	4.18
4	Brush Creek Inlet	7.93	336	21.3	86	8.28	0.31	2.6	3.4	2.29	6	0.43	0.088	177

Brush Creek

Station	Location	pH	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Nitrate-Nitrite N (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Dissolved Phosphate (mg/L)	Turbidity (NTU)
5	Lower watershed	7.73	358	20	90	8.3	0.46	2.4	4.3	1.94	6.7	0.35	0.12	160
6	mid watershed	7.6	377	19.5	89.7	8.2	0.3	2.1	3.8	1.8	5.9	0.37	0.099	103
7	Lower south fork	7.6	410	22	78	6.8	0.27	1.9	1.9	1.63	3.8	0.33	0.14	38.8
8	Lower north fork	7.6	393	22	86	7.9	0.3	2.3	2.4	2	4.7	0.31	0.13	44.7
9	Upper south fork	7.6	383	23	85	7.8	0.22	2.3	1.942	2.08	4.242	0.27	0.11	48.1
10	Upper north fork	7.5	388	23	79	6.9	0.32	2.5	5.1	2.18	7.6	0.31	0.12	51
11	Duplicate 5	7.75	349	20	91	8.3	-	-	-	-	-	-	-	-

RESERVOIR ANALYSIS



Lake Pool Water Quality Characteristics

Parameter	Epilimnion Sample (1-3 ft)	Hypolimnion Sample (18 ft)
Secchi Depth	2.1	-
1% Light Level (calculated)	5.7	-
pH	8.67	7.75
Conductivity	247 µmhos	394 µmhos
Temperature (°C)	31.7	16.1
% Dissolved Oxygen	138	1.1
Dissolved Oxygen	10.1 mg/L	0.1
Nitrogen, Ammonia	<0.10 mg/L	3.9 mg/L
Nitrogen, Kjeldahl	1.5 mg/L	4.9 mg/L
Nitrogen, Nitrate-Nitrite	0.026 mg/L	0.020 mg/L
Nitrogen, Organic	1.5 mg/L	1.0 mg/L
Nitrogen, Total	1.526 mg/L	4.920 mg/L
Phosphorus, Total	0.080 mg/L	0.40 mg/L
Phosphorus, Dissolved	<0.05 mg/L	0.13 mg/L
Turbidity	7.8 NTU	20 NTU
Chlorophyll-a	0.0 ug/L	4.0 ug/L

RESERVOIR & WATERSHED ASSESSMENT

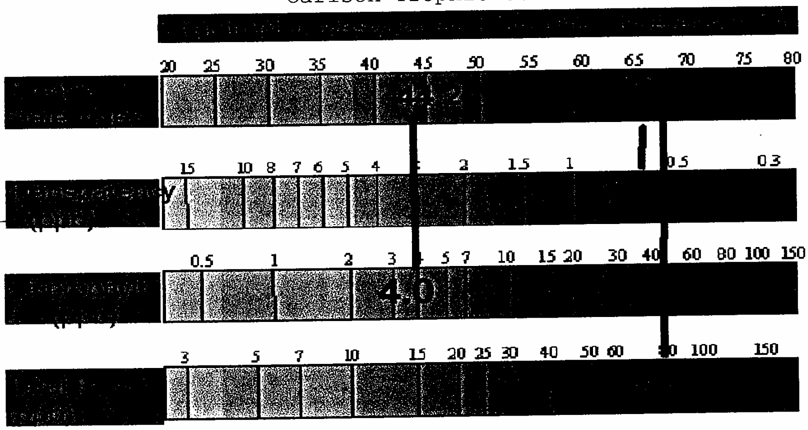
The Brush Creek Reservoir assessment resulted in data that indicates the reservoir has become eutrophic. Based on the IDEM Eutrophication Index, the reservoir scored 53 on a scale of 0 to 75 indicating eutrophication. Applying the Carlson Trophic State Index formulas netted similar results. Based on water transparency, the reservoir scored 66.2 and 67.3 based on Total Phosphorus. Chlorophyll-*a* measured in the reservoir resulted in a TSI of 44.2, which is in the mesotrophic range of that index however, chlorophyll-*a* sample filtering results may be skewed due to the use of the incorrect filters. That score then has been discarded. The Carlson scale ranges from 20 to 80 with scores in the high 60s being eutrophic to hypereutrophic.

Total phosphorus loading was plotted with Vollenweider curves that predict allowable and excessive loading based on the mean depth. Total P loading was calculated to be 0.128 $g/m^2/yr$, which is in the excessive range of the chart based on the mean depth of the reservoir.

IDEM EUTROPHICATION INDEX

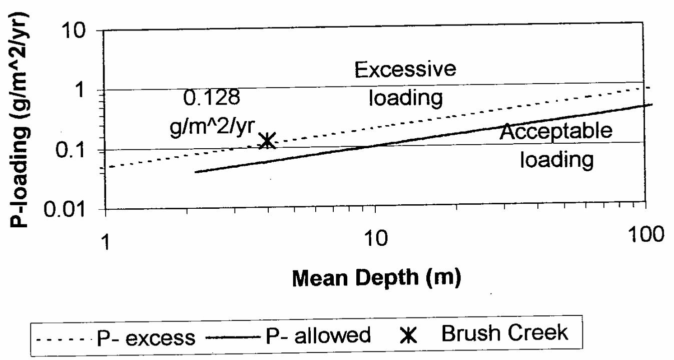
Parameter and Range	Eutrophy Points	Brush Creek Score
I. Total Phosphorus (ppm)	0-4	4
II. Soluble Phosphorus (ppm)	0-5	3
III. Organic Nitrogen (ppm)	0-4	3
IV. Nitrate (ppm)	0-4	0
V. Ammonia (ppm)	0-4	4
VI. Dissolved Oxygen (percent saturation at 5 ft from surface)	0-4	0
VII. Dissolved Oxygen (percent of measured water column with at least 0.1 ppm)	0-4	0
VIII. Light Penetration (Secchi disk)	0 or 6	6
IX. Light Transmission (percent of light transmission at depth of 3 ft by photocell)	0-4	3
X. Total Plankton (per liter of water sampled from a single vertical tow between 1% light level and the surface)	0-20	20
K. blue-green dominance add	10 pts.	10
Total		53

Carlson Trophic Scale



Should be metrs

Figure VII-2 Phosphorus Loading vs Vollenweider Phosphorus Loading/Mean Depth Relationship

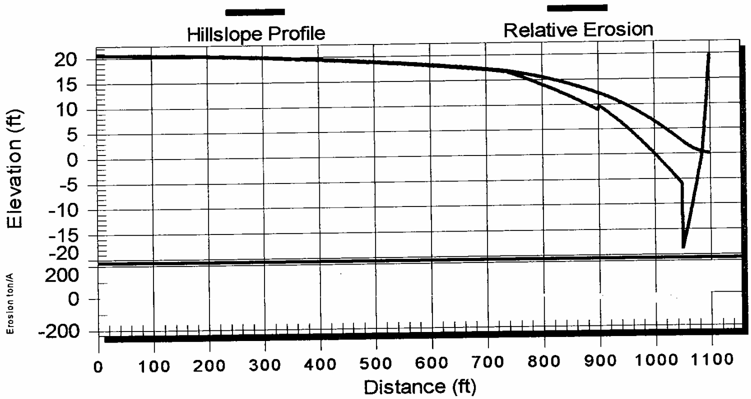


Watershed Erosion

A powerful computer simulation model, known as WEPP (Water Erosion Prediction Project), can simulate erosion processes and their interaction with management practices, to predict water erosion under varied scenarios. To accurately predict erosion, WEPP requires the user to specify erodibility values for different soil types. In WEPP, two major components of water erosion have been identified: rill erosion (erosion by water flowing in small channels) and interrill erosion (erosion by raindrop impact and sheet flow). WEPP assigns each soil a set of erodibility parameters, which represent the sensitivity of that soil to rill and interrill erosion. The model has been employed to predict sediment loss from a typical slope profile of the Cobbsfork-Avonburg soil map unit. Although the model has impressive capabilities, the simulation was limited to a hypothetical one-year period for cropland that is used in continuous corn and soybean production with conventional spring chisel plow tillage While these conditions may appear to represent an extreme scenario, the soil units, segment lengths, and slopes were taken directly from the soil survey. The following table and graph summarize the modeling results.

Brush Creek Cropland Typical Erosion					
Average Annual Precipitation 43.00 in Average Annual Runoff 2.30 in Average Annual Soil Loss 14.800 ton/A Average Annual Sediment Yield 13.400 ton/A					
Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
corn-spring chisel plow	1095.0	14.79	1086.0	62.44	9.0
corn-spring chisel plow	5.0	0.00	0.0	160.21	5.0
Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.89	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.25	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	54.54	150.0	0.00	0.0
IN\ HOLTON(SIL)	50.0	109.53	36.0	97.36	14.0

Figure VII-3 Typical Cropland Erosion Profile



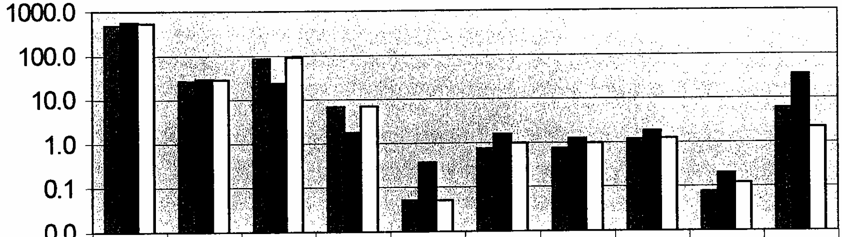
Livestock Impact

During the sample collection for baseline sampling, beef cattle were observed to have direct access to the tributary of Brush Creek at the location of sample point #9. Samples were collected from the pre-determined location with a herd of cattle in the stream at the time and location of sampling. Since sampling was performed in late summer, the cattle continued to loiter in the stream and did not seem to be disturbed by the sampling activity. A decision was made to add a sample point up stream of the area occupied by the cattle. This field decision was made to exploit the direct and immediate impact of cattle in a stream by characterizing water quality in a before and after setting.

Figure VII-4 shows that many of the parameters are impacted. The average values in the graph represent averages of sample locations 5-8, 9U, 10, and 11 for the select parameters. Sample location 9, due in part to its proximity to the county road intersecting the stream, was regarded as a highly visible stream where livestock access was easily documented. Other locations also were observed to have areas allowing livestock access to the stream.

Samples collected from location #9, compared to location #9U immediately upstream and averages of other locations, had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, slightly elevated temperature and conductivity readings, and elevated levels of Ammonia N, TKN, Organic N, Total N, Total P, and turbidity.

Figure VII-4
Brush Creek
Sample Location 9 vs Averages vs Upgradient Select Parameters



	Conductivity (µmhos)	Temp. (C)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	Ammonia N (mg/L)	TKN (mg/L)	Organic N (mg/L)	Total N (mg/L)	Total P (mg/L)	Turbidity (NTU)
▩ Average	484.6	26.0	85.8	6.6	0.1	0.7	0.7	1.2	0.1	5.9
■ 9	560	28.9	23.2	1.76	0.36	1.6	1.24	1.85	0.2	34
□ 9U	530	28	89	6.8	0.05	0.96	0.96	1.22	0.12	22

RECOMMENDATIONS

The recommendations for enhancing the water quality of Brush Creek center on:

- Reducing the generation of nonpoint sources of pollutants, particularly nutrients and sediment from the watershed.
- Reducing the delivery of nonpoint sources of pollutants to Brush Creek, the Brush Creek Reservoir, and the Vernon Fork Muscatatuck River.

Samples collected from Brush Creek proper and tributaries confirm watershed conditions that accelerate the eutrophication process. Storm water samples collected from ***all*** stream sampling locations had total P levels that were at least double the State standard. Dissolved phosphorus levels were also elevated.

This study has concluded that Brush Creek's lowered water quality may be a result of agricultural practices and overall lack of watershed management. Certain watershed conditions and prevailing practices warrant attention and further study by those wanting to preserve the habitat quality of Brush Creek and retard the eutrophication of Brush Creek Reservoir.

First, the loss of 95% of the natural wetlands combined with intensive agricultural production are circumstances that support the presence of elevated nutrients and sediment in the runoff from the watershed- especially in the upper regions found in Ripley County. Even though conservation tillage methods have likely helped to alleviate this condition, the silt and topsoil washed into the stream and reservoir during heavy rainfall events is still coating rocks and filling the pools and having a negative impact on the reservoir. Soil conservation efforts including conservation tillage and addition of filter strips should be intensified to prevent soil transport to the stream and reservoir. These grass buffers would also filter nutrients before they reach the waterways.

Next, wetland preservation, wetland restoration, and wetland construction should be pursued throughout the watershed- in that order. The development of additional wetlands to capture and treat agricultural fertilizer runoff deserves consideration in future studies.

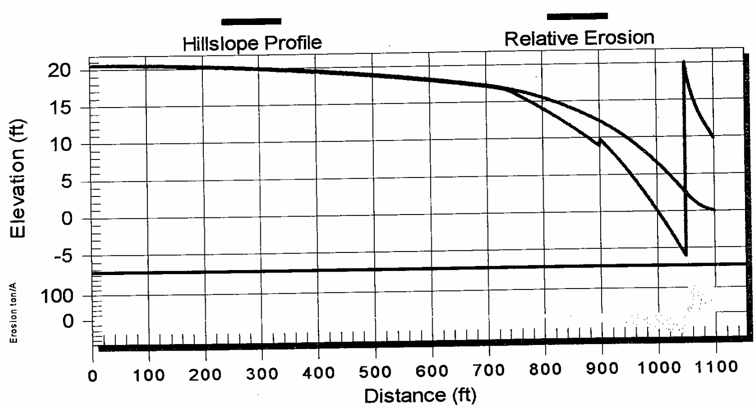
Third, access of cattle to the stream's ecosystem should be discouraged. The monitoring results at sample location #9 are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek.

1. Filter Strips

In the modeling effort presented earlier, the conditions modeled involved conventional cropland. The implementation of filter strips can be simulated by adjusting the management to change a strip of land at the field edge from cropland to permanent grass vegetation. In the following example, a 50-foot wide strip was modeled which caused the predicted average annual soil loss to change from 14.8 tons/acre to 11.6 tons/acre. Due to the trapping of sediment by deposition, the predicted reduction in average annual sediment yield decreased from 13.4 tons/acre to 5.3 tons/acre- a reduction of 60%.

Brush Creek Cropland Typical Erosion with Filter Strip					
Average Annual Precipitation 43.00 in Average Annual Runoff 2.00 in Average Annual Soil Loss 11.600 ton/A Average Annual Sediment Yield 5.300 ton/A					
Management	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
Corn-spring chisel plow	900.0	4.39	900.0	0.00	0.0
Corn-spring chisel plow	150.0	54.76	150.0	0.00	0.0
Grass	50.0	0.00	0.0	127.61	50.0
Soil Name	Segment Length (ft)	Average Detachment (t/acre)	Detachment Length (ft)	Average Deposition (t/acre)	Deposition Length (ft)
IN\ COBBSFORK(SIL)	400.0	0.90	400.0	0.00	0.0
IN\ AVONBURG(SIL)	300.0	1.78	300.0	0.00	0.0
IN\ ROSSMOYNE(SIL)	200.0	15.30	200.0	0.00	0.0
IN\ CINCINNATI(SIL)	150.0	54.76	150.0	0.00	0.0
IN\ HOLTON(SIL)	50.0	0.00	0.0	127.61	50.0

Figure VIII-2
Typical Cropland Erosion Profile with Filter Strips



As an edge-of-the-field best management practice, filter strips are regarded as a reactive measure to soil erosion as compared to a proactive measure. Filter strips are a tool for effecting soil deposition and could be categorized a "second best" management practice to measures that prevent soil detachment in the first place. Nevertheless, filter strips are recommended as first priority to prevent further degradation of water quality and sedimentation to the Brush Creek Reservoir.

Filter strips apply as a practice to treat sheet overland flow- primarily on cropland but also can be effective on pasture at the lower edge of fields. Filter strips are also appropriate to install above conservation practices such as terraces or diversions. They area especially recommended, for purposes of this study, adjacent to Brush Creek and its tributaries. As edge-of-the-field management practices, filter strips should be used in conjunction with other best management practices that make an impact ***within*** the field. It should be recognized that best management practices can complement each other and, in many situations, BMPs need to be combined to optimize their benefits.

In general, the same considerations apply for the installation of a filter strip as for the establishment of a pasture or meadow. However, land grading or other soil surface preparations may be necessary to ensure that the filter will function properly, and that runoff will enter the filter in the form of shallow, uniform flow. A filter strip designed by a technical agency (i.e., NRCS or IDNR) should show the final filter grade and dimensions on the plan or staked in the field. Once the type of vegetation is selected, soil fertility should be evaluated, and the seeding method selected. The amount of fertilizer and lime to be applied to the filter should be determined from the soil analysis taken from the cropland. Rapid filter-strip establishment is critical.

2. Wetlands

Based on an analysis of the hydric soils mapped in the soil surveys of Jennings and Ripley counties and located in the Brush Creek watershed, there were approximately 2,795 acres of wetlands in the Brush Creek watershed 200 years ago. Combining the information from the NWI and the assessment of hydric soils mapped in the soil surveys yields the following summary:

• Total land area	9,240 acres
• Estimated wetlands circa 1780s	2,795 acres
• Percent of surface area in wetlands circa 1780s	30.2%
• Existing wetlands	124 acres
• Percent of surface area in wetlands today	1.3%
• Percent of wetlands lost	95%

This assessment suggests that wetland loss within the Brush Creek watershed is somewhat greater than the loss experienced Statewide during the same time period. The majority of this loss is attributed to artificial drainage and conversion to cropland.

When properly managed, wetlands can help prevent non point source pollution from further degradation of the water quality within the Brush Creek Reservoir and Brush Creek itself. Figure

IX-1 presents six possible locations for consideration as wetland sites. These sites are identified based on their proximity to intensive agricultural production with the criteria set to intercept runoff from these areas, to trap sediments in the runoff, and to assimilate nutrients associated with the runoff itself and the sediment deposited.

Properly managed wetlands can intercept runoff and transform and store non point source pollutants like sediment, nutrients, and certain heavy metal s without being degraded. In addition, wetland vegetation can keep stream channels intact by slowing runoff and by evenly distributing the energy in runoff. Wetland vegetation also regulates stream temperature by providing streamside shading.

3. Livestock Exclusion

Within the Brush Creek watershed, beef cattle herds are not the primary enterprises of the farms. The Indiana Agricultural Statistics 2001 Beef Cow Inventory report states that Jennings County ranks 24th in the State with 3,100 beef cows. Ripley County, with 5,000 beef cows, ranks 9th, however those are believed to be more concentrated to the southeast part of the county based on the distribution of prime farmland across the county.

Samples collected from location #9 had parameters that confirmed the presence of a degraded water quality believed to be directly attributable to livestock access to the stream. Samples had low levels of dissolved oxygen, slightly elevated temperature and conductivity readings, and elevated levels of Ammonia N, TKN, Organic N, Total N, Total P, and turbidity.

These results are considered justification for regarding livestock exclusion from the streams in the watershed as a priority for minimizing the continued degradation of the water quality to Brush Creek. Access of cattle to the stream's ecosystem should be discouraged. Based on the observations of the apparent management regimes of cattle operations along the stream ecosystems, those subwatersheds with the highest concentrations of cattle operations should be focused on.

Any practice that reduces the amount of time cattle spend in a stream, and hence reduces the manure loading, will decrease the potential for adverse affects of water pollution from grazing livestock. It has been shown that providing a water trough as an alternative drinking source may reduce the instream fecal deposition during the winter by as much as 90 percent (Moore et al. 1993). In addition, Clawson (1993) found that summer stream use dropped from 4.7 min/cow/day to 0.9 min/cow/day and bottom land use dropped from 8.3 to 3.9 min/cow/day when a water trough was provided as an alternative water source. This indicates that reductions of creek use by cattle can be achieved without fencing them out of the creek, however exclusion by fencing is preferred.

The recommendations, for the most part, involve private land where lack of incentive and financial ability on the landowner's part may limit implementation. Cost-sharing assistance may be available through the Lake and River Enhancement Program and other State or Federal programs.